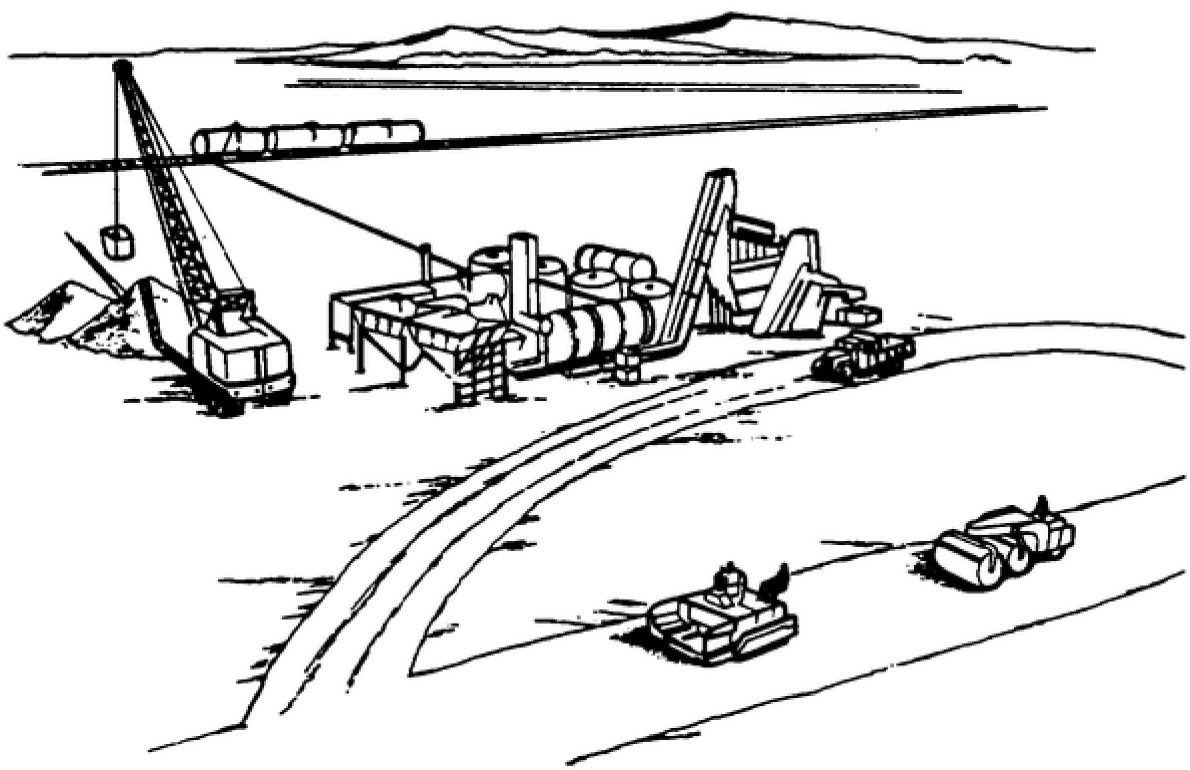
SUBCOURSE EN5459

EDITION 6

BITUMINOUS PAVEMENTS



THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

AIPD

READINESS/ PROFESSIONALISM THRU GROWTH

US ARMY ENGINEER

BITUMINOUS PAVEMENTS
SUBCOURSE EN 5459

US Army Engineer School
Fort Belvoir, VA

Nine Credit Hours

GENERAL

The Bituminous Pavements subcourse is denied to provide information on determining the components and classification of bituminous material; estimating materials required; planning and managing the placement of bituminous surfaces; estimating tie required; determining required aggregate gradation specification; managing operation of a hot mix plant; and supervising maintenance of bituminous surfaces. The subcourse contains seven lessons. Each lesson corresponds to a terminal learning objective.

Lesson 1: COMPONENTS AND CLASSIFICATION OF BITUMINOUS MATERIALS

TASK: Determine the components and classification of bituminous materials.

CONDITIONS: Given this subcourse, a No. 2 pencil, paper, and an ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75% of the examination questions.

Lesson 2: MATERIAL REQUIREMENTS FOR BITUMINOUS SURFACING OPERATION

TASK: Estimate material requirements for bituminous surfacing operations.

CONDITIONS: Given this subcourse, a No. 2 pencil, paper, and an ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75% of the examination questions.

Lesson 3: PLACEMENT OF BITUMINOUS SURFACES

TASK: Plan the placement of bituminous surfaces.

CONDITIONS: Given this subcourse, a No. 2 pencil, paper, and an ACCP Examination Response Sheet.

STANDARD: Demonstrate competency of the task skills and knowledge by responding correctly to 75% of the examination questions.

Lesson 4: TIME REQUIREMENTS FOR HOT MIX PLANT PLACEMENT

TASK: Estimate the time required for hot mix plant placement.

CONDITIONS: Given this subcourse, a No. 2 pencil, paper, and an ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75% of the examination questions.

Lesson 5: AGGREGATE SPECIFICATIONS FOR BITUMINOUS HOT MIX OPERATION

TASK: Determine the required aggregate gradation specifications for Bituminous hot mix operations.

CONDITIONS: Given this subcourse, a No. 2 pencil, paper, and an ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75% of the examination questions.

Lesson 6: OPERATION OF A HOT MIX PLANT

TASK: Plan operation of a hot mix plant.

CONDITIONS: Given this subcourse, a No. 2 pencil, paper, and an ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75% of the examination questions.

Lesson 7: MAINTENANCE OF BITUMINOUS SURFACES

TASK: Plan maintenance of bituminous surface.

CONDITIONS: Given this subcourse, a No. 2 pencil, paper, and an ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75% of the examination questions.

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INTRODUCTION

In recent years bituminous materials have become tremendously important in the construction of roads and airfields for both military and civilian use. A basic knowledge of these bituminous materials, their origin, composition, types, and grades, is essential for an understanding of their use in construction. Knowledge of the classification and desirable characteristics of the aggregates used in bituminous construction is also of primary importance to the engineer charged with the responsibility of planning, designing, and constructing bituminous wearing surfaces.

***** IMPORTANT NOTICE *****

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%.

PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

Lesson 1
COMPONENTS AND CLASSIFICATION OF BITUMINOUS MATERIALS

TASK: Determine components of Bituminous Materials

CONDITIONS: Given this subcourse, a No. 2 pencil, a calculator (recommended) and an ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75 percent of the examination questions.

CREDIT HOURS: 1

REFERENCES:
TM 5-337, Paving and Surfacing Operations
ST 5-330-8, Special Text, February, 1972

Learning Event 1
ADVANTAGES AND LIMITATIONS OF BITUMINOUS SURFACING

INTRODUCTION

All bituminous materials are composed largely of bitumen, a black solid that gives bituminous binders their black color, cementing ability, and waterproofing properties. Even though all bituminous materials are black in color and are composed mainly of bitumen, their physical properties differ greatly. Bituminous materials are classified into two main groups by origin: Asphalts and Tars. These are the two bituminous materials used in the construction of roads and airfields.

Bituminous surfaces are composed of compacted aggregate and bitumen (binder). The aggregate transmits the load from the surface to the subgrade, takes the abrasive wear of the traffic, and provides a nonskid surface. The functions of the binder are twofold. It binds the aggregate together, thus preventing the displacement and loss of the aggregate. The binder also provides a waterproof cover for the base and keeps surface water from seeping into and weakening that material.

Pavements constructed with bituminous materials are economically, easily, and quickly, placed. For this reason, these materials have gained tremendous importance to the military engineer in the construction of roads and airfields.

Remember, the bituminous surface of a road or airfield is an important part of construction. Do it right the first time.

Advantages

Bituminous surfaces are particularly adaptable to stage construction. Additional courses can be added to existing pavements to provide further reinforcement if the loads or density of traffic increases. The flexibility of bituminous surfaces permits slight adjustment caused by settlement of the subgrade without detrimental effect. Bituminous wearing surfaces provide a resilient, waterproof medium that protects the base course from water and traffic. Properly designed bituminous wearing surfaces, when compared with concrete, are less affected by temperature strains. Bituminous surfaces resist wear, weathering, and deterioration from aging with only minimal maintenance.

While it is true that bituminous materials are highly versatile, and serve admirably in temporary, expedient, and light traffic situations (where concrete is not justifiable), it is equally true that thicker bituminous pavement designed for heavy and continuing duty are fully comparable to concrete designed for the same service, consisting of heavy volumes of traffic or heavy wheel loads. This is true not only for highways, roads and streets, but also for airfields.

Limitations

Bituminous wearing surfaces lack appreciable bearing action to carry wheel loads over weak spots in the subbase. For this reason, the subgrade must have an adequate, uniform bearing strength and the base course must have adequate thickness, bearing capacity, and cohesion. Structures containing bitumens oxidize, thus losing their resilience with age. This is a major limitation when a proposed project is to be of a standby nature.

Learning Event 2
TYPES AND GRADES OF ASPHALT

Asphalt is a natural or manmade by-product of petroleum distillation. Natural asphalt is found in nature as either lake (or pit) asphalt or rock asphalt. There are three types of asphalt:

- asphalt cement
- asphalt cutbacks
- asphalt emulsions.

ASPHALT CEMENT

Asphalt cement is a solid. The Corps of Engineers specification covers three (3) types of asphalt cement:

- HARD: for hot climates (Egypt, Arizona, Texas)
  40-50 Penetration or AP-7 or AC-40
  60-70 Penetration or AP-5 or AC-20
- MEDIUM: for moderate climates (Virginia, Missouri, Kansas, Germany)
  85-100 Penetration or AP-3 or AC-10
  120-150 Penetration or AP-1 or AC-5
- SOFT: for cold climates (Alaska, Maine, Minnesota)
  200-300 Penetration or AP-00 or AC-2.5

Each grade is designated by a penetration grade or AP or AC numbers.

ASPHALT CUTBACKS

The special equipment needed to heat asphalt cements is not always available. Since asphalt must be in a fluid condition to spray or to mix with an aggregate, the solid asphalt cement would not be suitable. A more fluid asphaltic material requires less heating than asphalt cement to secure proper spraying and mixing consistencies. This is obtained by combining an asphalt cement with a petroleum distillate. The distillate used is called a "cutterstock" and the product of the combined materials is called "asphalt cutback."

Upon exposure to atmospheric conditions the distillates evaporate, leaving the asphalt cement to perform its function. This rate of evaporation deter mines the type of asphalt cutback.

Types of Asphalt Cutbacks

- <u>Rapid-Curing (RC)</u>. Composed of asphalt cement and a gasoline or naphtha with a curing time of 4 to 8 hours.
- <u>Medium-Curing (MC)</u>. Composed of asphalt cement and a kerosene or JP-4, with a curing time of 12 to 24 hours.

- Slow-Curing (SC). Composed of asphalt cement and diesel fuel, with a curing time of 48 to 60 hours.
- Road-Oil. A heavy petroleum oil.

Grades of Asphalt Cutbacks

If a great amount of cutterstock is added to a given amount of asphalt cement, a very thin liquid will result. Different amounts of cutterstock are added to a given amount of asphalt cement (AC) to obtain various thicknesses or viscosity grades of cutbacks. A new set of specifications for asphalt cutbacks has been approved by the Corps of Engineers. This specification covers the following types and viscosity grades (Kinematic Viscosity):

- Rapid-Curing (RC) -70,250,800,3000
- Medium-Curing (MC) -30,70,250,800,3000
- Slow-Curing (SC) - 70, 250, 800, 3000

ASPHALT EMULSIONS

It is often advantageous to use as asphalt material that is liquid at room temperature and yet will not burn. Asphalt emulsions (emulsified asphalts) possess these properties.

Asphalt emulsions are composed of asphalt cement, water, and an emulsifier mixed together to produce a liquid material. Asphalt and water will not mix alone so a chemical agent called an "emulsifying agent" must be added. It is this emulsifying agent that enables the asphalt and water to mix. Common emulsifying agents are soaps, animal blood, chemicals, and certain specified colloidal clays in dust.

Emulsified asphalts may be of either the anionic electro (negatively) charged asphalt globules, or cationic electro (positive) charged asphalt globules, depending upon the emulsifying agent.

TABLE 1. TYPES OF ASPHALT EMULSIONS

Types and Grades					
ANIONIC (-)			CATIONIC (+)		
Rapid Setting	Medium Setting	Slow Setting	Rapid Setting	Medium Setting	Slow Setting
RS-1, 2	MS-2	SS-1, 1h	RS-2K, 3K	*SM-K, **CM-K	SS-K, SS-Kh

*SM indicates mixing grade.
**CM indicates coarse mixing grade

Learning Event 3
TYPES AND GRADES OF TARS

TYPES OF TARS

Tars consist of road tars and road tar cutbacks.

Road Tar (RT)

Road tar is manufactured in twelve grades based on viscosity or hardness. Grades 1 through 7 are liquid at room temperature, while grades 8 through 12 are semi-solid to solid at room temperature. The difference in the liquid and solid grades of road tars is that the liquid road tars contain more of the of the liquid coal distillates than do the solid grades.

Road Tar Cutback (RTCB)

In the same manner that asphalt can be cut back with a petroleum distillate, so can road tars be cut back with a coal tar distillate. Road tar cutbacks are manufactured in two viscosity grades only, grades 5 and 6. The more volatile coal distillates such as benzene or a solution of naphthalene in benzol may be used to cut back the heavier grades of road tar to produce the RTCB 5 and 6. These RTCBs react much like the RC asphaltic cutbacks in that they cure rapidly.

ADVANTAGES/DISADVANTAGES OF ROAD TAR

Advantages. Not only can tars do almost any job that asphalt can, but they even have some advantages over them. Probably the biggest advantage of tars is that they do not dissolve in petroleum distillates as do asphalts. This is an advantage where there is danger of petroleum distillates being spilled on the surface, such as jet fuel and gasoline on such areas as refueling and parking aprons and gasoline and oil dispensing services. The asphalts in an asphalt surface could, and have been, dissolved by spilled petroleum distillate but since tars are products of coal they would not be dissolved. Tars also seem to have better penetrating qualities than asphalts. If a tar and an asphalt of equal viscosities and curing rates were applied to a soil base, a tar would penetrate deeper into the base than the asphalt.

Disadvantages. Tars, however, have a disadvantage that stems from the fact that they are subject to extreme consistency variations with only average temperature changes. In the summer when it is hot, a tar binder may get so soft that the tar mix pavement may become so brittle that it will crack and cause the pavement to disintegrate.

Tar-Rubber Blend

The Corps of Engineers has become interested in the use of tar-rubber blends as a binding agent for flexible pavements that will be resistant to the detrimental effects of jet fuel spillage and jet blast. The blend consists of a mixture of unvulcanized rubber, a type that is resistant to petroleum oils or distillates, and high temperature coal tar of the coke oven type.

Learning Event 4
TYPES, CHARACTERISTICS AND GRADATION OF AGGREGATES

In bituminous constructions, it is common to classify aggregate according to its particle size. The particle size is designated by the sieves that the particle passes through and on which it is retained. There are three types of aggregates based on this system of classification.

Coarse Aggregate

Material too large to pass through the openings in a #8 standard sieve is normally classified as coarse aggregate.

Fine Aggregate and Sand

The particles that are small enough to fall through the openings in a #8 sieve, but too large to pass the #200 sieve are classified as fine aggregate and sand.

Mineral Filler (Dust)

If the piece of aggregate under consideration is small enough to pass the #200 sieve, it is classified as mineral filler or mineral dust.

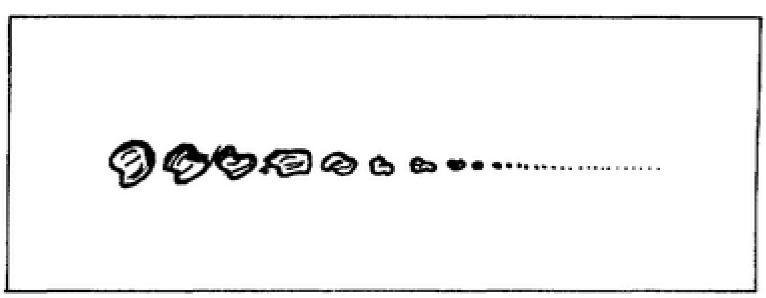
TYPES OF AGGREGATE GRADATION

The three different sizes or types of aggregates may be combined in different proportions to produce various aggregate gradations. There are four major aggregate gradations that are used in bituminous construction.

Dense Gradation

When coarse aggregate, fine aggregate, and mineral filler are combined in proper proportions, the resulting blend or gradation is called dense gradation. It includes a good representation of all the particle sizes including mineral filler. "Dense" means there are no voids in the blend. This type of gradation is only used in a plant mix or hot mix.

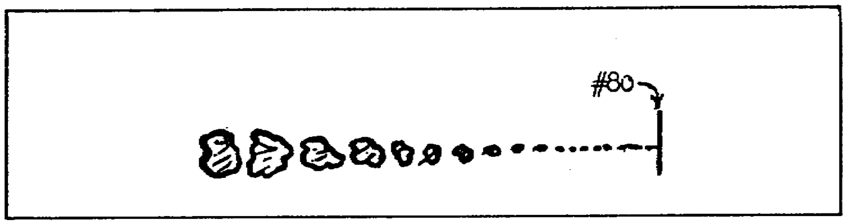
FIGURE 1. DENSE GRADATION



Open Gradation

The mix contains a range of sizes of coarse aggregate, fine aggregate, and mineral filler. "Open" describes the blend. It has voids or unfilled spaces in it, and a good representation of all particle sizes, down to the #80 sieve. Below the #80 sieve, there are gaps in the particle sizes. It is used only for road mixes (mix in place).

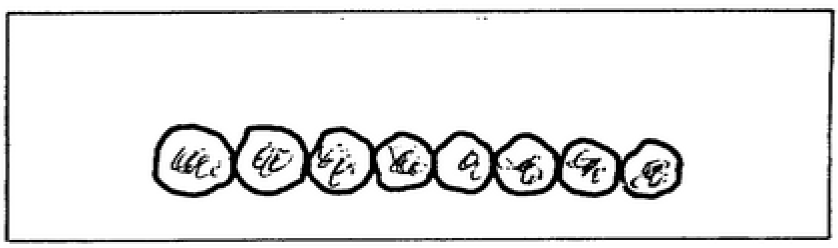
FIGURE 2. OPEN GRADATION



Uniform Gradation

Uniform gradation consists of aggregate particles which are all approximately the same size. The particle size is less than one inch. Uniformly graded materials are used extensively as cover aggregates for surface treatments, seal coats, etc.

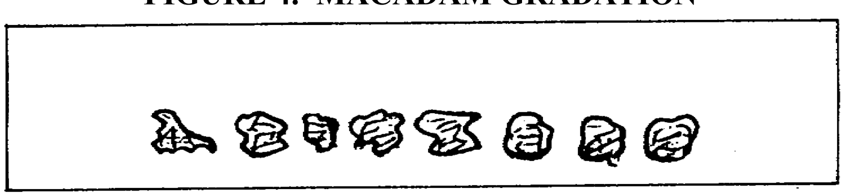
FIGURE 3. UNIFORM GRADATION



Macadam Gradation

A macadam graded aggregate consists of coarse, uniformly graded aggregate particles (all about the same size- to 3 inches).

FIGURE 4. MACADAM GRADATION



Aggregates are angular in shape and rough in surface texture. Aggregates very seldom occur in nature as angular, so it necessary in most cases to crush the aggregate to obtain the desired angular particles.

Learning Event 5
FIELD IDENTIFICATION OF UNKNOWN BITUMINOUS MATERIALS

Identifying unknown bituminous materials has been, and still is, a major problem. Stockpiled bituminous materials that are unmarked or improperly marked can cause unnecessary delay in construction. Some of the tests used in the field to identify bituminous materials are:

- Solubility
- Pour
- Smear
- Heat-Odor
- Penetration
- Stone coating.

Solubility Test. The solubility test consists of taking a small amount of the unknown bituminous material, enough to cover the head of a nail if a solid, or a few drops of a liquid material, and attempting to dissolve the material by stirring it in a petroleum distillate, i.e., gasoline, kerosene, diesel fuel, etc. If the material is an asphalt it will mix uniformly with the distillate. Tars, however, will form a stringy undissolved mass. Emulsions, in addition to other distinguishing tests, may also be identified in the solubility test since they will form undissolved wads or balls of the emulsion at the bottom of the container of petroleum distillate.

Pour Test. If, upon performing the solubility test, the bituminous material dissolves, an asphalt product-asphalt cement or asphalt cutback-is present. All asphalt cements are solids at room temperature (77°F), while asphalt cutbacks, on the other hand, are fluids. With these facts in mind, you may run a second test, a pour test, to determine whether a sample is an asphalt cement or an asphalt cutback.

In the pour test, an attempt is made to pour the material from a small container. Asphalt cements, being solids, will not pour, while asphalt cutbacks, being fluids at 77°F, will pour.

Smear Test. The smear test is used to separate an RC from an MC or SC. It is primarily based on the fact that RCs are cut back with a highly volatile material (naphtha or gasoline). It is possible to tell whether a sample is an RC or not by smearing some of in a thin layer on a nonabsorbent surface such as a piece of glazed paper. This will give the volatiles a chance to evaporate. In fact, volatiles will leave an RC smear within a few minutes. The surface will become extremely tacky; sufficiently so that the specimen, paper and all, will stick to your fingers and be lifted into the air if touched. Checking the reverse side of the paper you will find that the RC did not penetrate through the paper as will MCs or SCs. MCs and SCs on smear test will remain fluid and oily for some time; for hours or days in some cases, depending upon the type and grade of the material.

If an 800 or 3000 grade MC or SC is present though, it, too, may become sticky in a few minutes since there is already such a small amount of cutter-stock in it. When such a viscous grade is present, it is well to confirm the identification of the sample by a Prolonged Smear Test. Generally, the MCs and SCs will penetrate through the paper while the RCs will not. You can determine this by observing the back side of the paper.

In a Prolonged Smear Test, a thin smear is made on nonabsorbent paper and allowed to completely cure. If the viscous cutback is an RE-3000, it will cure completely in about three hours. When the spot has cured completely (the cutterstock has almost all evaporated) the smear will be almost pure AC and will be hard and no longer sticky. If the viscous sample were an MC or SC-800 or 3000, the spot would still be uncured and, therefore, very sticky, even after 24 hours, while the RC smear will have become a hard, glazed spot.

Heat-Odor Test. To differentiate MCs and RCs, their major differences must be emphasized. Probably the main difference between the two lies in the fact that one has kerosene as its cutterstock, while the other has been mixed with the diesel or slowly volatile oil class. Perhaps some people can tell the difference by odor alone, at room temperature, but this is not always reliable. Perform the heat-odor test to definitely establish the sample as an MC or SC. Apply heat to the sample in order to drive off the kerosene if it is present, and to make it show up in the form of an odor. It is best to heat the sample in a dosed container in order to capture the escaping vapors, being careful not to apply too much heat. If the sample is an MC, it will have a strong petroleum odor or a definite kerosene odor. On the other hand, should the sample be an SC, no kerosene or petroleum odor will be detected. An SC may have a faint odor of hot motor oil.

The ability to tell an RC from an MC and an SC from either is perhaps as important as any part of field identification. With various cutback materials, construction methods vary widely, and the properties of the final surface are likewise entirely different in many cases.

Field Penetration Test. Assuming that the unknown material mixes with a petroleum distillate, and will not pour, it is established that it is an asphalt cement. Now, you must designate the penetration grade of the asphalt and identify the sample as an asphalt cement either hard, medium, or soft.

The field penetration test is performed to approximately fix the hardness of the asphalt, not to pinpoint its exact penetration number. It is sufficient to know whether it falls in the hard, medium, or soft groups. This is sufficient information for planning or in some cases actually starting emergency construction for it indicates what construction methods and equipment will be suitable and what approximate application of mixing temperature may be used.

To perform this test, attempt to push a sharpened pencil or nail into the container of asphalt (at about 770) using a firm strong pressure. "Strong" is

meant to be perhaps a 10 pound pressure. If only a slight penetration is made, with considerable difficulty, a hard asphalt cement is present. If the penetration is made without great difficulty-slowly, perhaps, but positively, and to any desired depth, probably a medium asphalt cement is present. If the penetration is made with ease, the asphalt cement is naturally in the high penetration scale (a soft AC). Even the highest penetration grade will not pour at 77° or even immediately deform, if the container it is in is tilted.

Stone Cutting Test. Where a material has been tested and found to be an emulsion, it is necessary to know whether it is a Rapid Setting emulsion, termed as a "non-mixing" grade, or a Medium or Slow Setting emulsion, the latter two types being termed "mixing" grade emulsions. It is important to know which type is present since the uses of the mixing and non-mixing types vary greatly. The test performed to distinguish between these two kinds of emulsions is the stone coating test.

This test consists of taking a handful of damp sand and adding to the sand a small amount of emulsion (estimate about 6 to 8 percent by weight) and attempting to mix the two materials. Care should be exercised not to add so much emulsion to the sand as to saturate it.

A Rapid Setting emulsion will "break" so quickly it will not be possible to mix it with sand. It breaks immediately, gumming up the mixing spoon and the aggregate with asphalt cement. On the other hand, if the unknown sample is a Medium or Slow Setting emulsion, the material, when added to the damp sand, will mix easily and coat all the particles completely, as well as the mixing spoon, with a uniform coating of asphalt.

It is not necessary to attempt to determine the viscosity grade of an emulsion since there are so few grades. Simply find out whether the emulsion is a mixing or non-mixing grade. This is sufficient identification for field conditions. Likewise, by means of field identification, it is not necessary to distinguish between an MS and an SS, since both are mixing grades, and largely used for the same jobs.

PRACTICE EXERCISE FOR LESSON 1

Instructions

Check your understanding of Lesson 1 by completing the practice exercise. There is only one correct answer to each question. Try to answer all of the questions without referring to the lesson materials.

When you have completed all of the questions, turn the page and check your answers against the correct responses. Each correct response is referenced to specific portions of the lesson material so that you can review any questions you have missed or do not understand, before continuing to the next lesson.

1. What does a bituminous wearing surface provide?
   a. asphalt cement
   b. waterproofing
   c. rapid curing
   d. mineral filler

2. One function of a bituminous binder is to:
   a. hold the aggregate together.
   b. bind the tars to the surface.
   c. bind the asphalt to the road surface.
   d. help the surface water to seep into the road base.

3. What type of asphalt cutback is composed of asphalt cement and gasoline?
   a. rapid-curing
   b. medium-curing
   c. slow-curing
   d. road oil

4. What type of aggregate gradation consists of aggregate particles that are all approximately the same size?
   a. dense
   b. fine
   c. open
   d. uniform

5. What are two characteristics of aggregate?
   a. soluble and rough
   b. nonskid and smooth
   c. rough and angular
   d. soft and dense

ANSWER SHEET FOR PRACTICE EXERCISE

Lesson 1	Learning Event
1. b	1
2. a	1
3. a	2
4. d	3
5. c	4

Lesson 2
MATERIAL REQUIREMENTS FOR BITUMINOUS SURFACING OPERATIONS

TASK: Estimate Material Requirements for Bituminous Surfacing Operations

CONDITIONS: Given this subcourse, a No. 2 pencil, a calculator (recommended, and a ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75 percent of the examination questions.

CREDIT HOURS: 2

REFERENCES:
TM 5-337, Paving and Surfacing Operations
ST 5-330-8, Special Text, Flexible Pavements

Learning Event 1
IDENTIFICATION AND ESTIMATION OF MATERIALS

INTRODUCTION

Many different combinations of materials are used on bituminous surfaces. This part of the lesson will cover the materials used in treatments and pavements:

- Preliminary treatments
- Surface treatment
- Road mix
- Hot plant mix

PRELIMINARY TREATMENT

Before a bituminous surface is placed, the surface to be covered generally requires the placing of a preliminary treatment, a primer or a tack coat.

Prime Coat

Prime coats are placed on a dirt or gravel surface. The purpose of priming is to waterproof and dust proof the surface, plug capillary voids, and coat and bond loose particles. It also hardens or toughens the surface, promotes adhesion between the existing surface and the new surface, and penetrates the surface to 1/4".

Materials

The priming material may be:

- a low viscosity tar, such as RT-2, RT-3, or RT-4;
- a low viscosity asphalt such as MC-30, -70, -250, or SC-70, -250, -800; or
- a diluted asphalt emulsion. Bituminous materials for the prime coat should be applied in quantities of not less than 0.2 gallon or more than 0.5 gallon per square yard. The exact quantities can be determined by a test strip. Apply enough to perform the objectives listed above and let cure.

Estimation for a Prime Coat

To estimate the amount of bitumen required for the prime coat, multiply the area to be treated by the rate of application. The estimate must include sufficient bitumen for an additional width of 1 foot on each side of the surface course to be constructed on the primed base.

The formulas for a prime coat estimate are:

$$G = \frac{L \times (W + 2) \times AR_B \times LF}{9} = \text{GALs, or}$$

$$D = \frac{L \times (W + 2) \times AR_B \times LF}{9 \times 53} = \text{DRUMS},$$

where:

G = gallons of bitumen primer

D = drums of bitumen primer

L = length of treated section in feet. (Miles may be converted by multiplying by 5,280)

W = width of treated surface in feet

AR_B = rate of application of bitumen in gallons per square yard

LF = loss factor bitumen = 5% or 1.05

9 = square feet pet yard conversion factor

53 = gallons per drum

Example: The specifications and other data for a prime coat project are as follows:

L = 3 miles = 3 x 5280 = 15,480 feet

W = 24 feet

AR_B = 0.3 gal/sq yd

LF = 5 percent (or) 1.05

Find the number of gallons of bitumen (G) necessary to do this project

SOLUTION:

$$G = \frac{15{,}480 \times (24 + 2) \times 0.3 \times (1.05)}{9} = \frac{129729.6}{9}$$

= 14414.4 6 14,415 gallons.

TACK COAT

A tack coat is a coating of asphalt on an existing paved surface that provides a bond between the existing surface and the new surface. The two essential properties of a tack coat are: (1) it must be very thin; and (2) it must uni-

formly cover the entire surface of the area. When tack coats are too heavy, they leave a surplus of asphalt that bleeds into the overlying course. A thin tack coat does no harm to the pavement. A thin coat will properly bond the courses.

Materials

Tack coat materials may be: (1) a road tar, grade RTCB5-6, RT-6, 7, 8, 9, 10, or 11; (2) an asphalt cutback such as RC-250, or -800; (3) a diluted emulsion; or (4) an asphalt cement such as an AP-3 (85-100 penetration) or AP-1 (120-150 penetration).

Quantities to be Applied

Bituminous materials for the tack coat should be applied in quantities not less than 0.05 or more than 0.25 gallon per square yard. The exact quantity will depend upon the condition of the surface to be tacked.

Estimation for a Tack Coat

The procedure for estimating the bitumen required for a tack coat is similar to that described for a prime coat except that the tack coat is applied only over the proposed width of the pavement. The formulas for a tack coat are:

$$G = \frac{L \times W \times AR_B \times (LF)}{9} = \text{gallons (or)}$$

$$D = \frac{L \times W \times AR_B \times (LF)}{9 \times 53} = \text{drums}$$

where;

G = gallons of bitumen

D = drums of bitumen

L = length of treated section in feet

W = width of treated section in feet

AR_B = rate of application of bitumen in gallons per square yard

LF = loss factor for bitumen, 5% or 1.05

9 = square feet per square yard conversion factor

53 = gallons per drum

Example: The specifications and other data for a tack coat project are as follows

L = 2.7 miles = 2.7 x 5,280 = 14,256 feet

W = 24 feet

AR_B = 0.05 gal/sq yd

LF= 5 percent or 1.05

Find the number of drums of bitumen that will be needed to do this project.

SOLUTION:

$$D = \frac{14{,}256 \times 24 \times 0.05 \times 1.05}{9 \times 53} = \frac{17962.56}{477}$$

= 37.65 6 38 drums

SURFACE TREATMENT

Bituminous materials and aggregate are combined in various proportions to obtain the most satisfactory surface for a given situation, but will not add any strength to where they are applied. Accurate estimates are required to avoid production delays from inadequate supplies. You also want to avoid over supply and waste of materials.

The formula for estimating supplies for a single surface treatment is:

$$P = \frac{L \times W \times AR_A \times LF}{9} = \text{pounds (or)}$$

$$T = \frac{L \times W \times AR_A \times LF}{18{,}000} = \text{tons of aggregate.}$$

The formula for bitumen determination is:

$$\frac{L \times W \times (AR_B \times AR_A) \times LF}{9} = \text{gallon}$$

where:

P = weight of aggregate in pounds

T = weight of aggregate in tons

L = weight of treated surface in feet

W = width of treated surface in feet

AR_A = rate of application of aggregate in pounds per sq/yd.

AR_B = rate of application of binder per pounds of aggregate per sq/yd.

LF = loss factor for bitumen 5% or 1.05

9 = square feet per square yard conversion factor

18,000 = 2,000 x 9 or pounds per ton and square feet per square yard conversion factor

The materials for a multiple surface treatment are determined by the same method as above except that the application rate of the binder and the aggregate, and the size of the aggregate are one-half that of the previous lift.

Example: A teat strip with an area of 100 square yards was used to determine the quantities for a single surface treatment. Careful control was made of materials. A check of materials consumed showed that 1.50 tons of aggregate was used. Based on previous experience an aggregate loss of 10 percent (0.10) and a bitumen loss of 5 percent (0.05) are expected. Find the tons of aggregate and drums of bitumen necessary to make a double surface treatment on a road 24 feet wide and 10 miles long.

SOLUTION:

(1) Aggregate 1st Lift

$$AR_A = \frac{1.50 \text{ tons x } 2000 \text{ lb/ton}}{100 \text{ sq yd}} = 30 \text{ lb/sq yd}$$

$$T = \frac{(10 \times 5{,}280) \times 24 \times 30 \times 1.10}{18{,}000} = \frac{41{,}817{,}600}{18{,}000}$$

$$= 2323.2 \text{ ð } 2324 \text{ tons}$$

Aggregate 2nd Lift

$$T = \frac{10 \times 5{,}280 \times 24 \times 15 \times 1.10}{18{,}000} = \frac{20908800}{18000}$$

$$= 1161.6 \text{ ð } 1162 \text{ tons}$$

(2) Bitumen 1st Lift AR_B = 0.01 gallon per lb of aggregate per sq/yd

$$B = \frac{(10 \times 5{,}280) \times 24 \times (30 \times 0.01) \times 1.10}{9 \times 53} = \frac{418176}{477}$$

$$D = 876.67 \text{ ð } 877 \text{ drums}$$

Bitumen
2nd Lift

$$D = \frac{(10 \times 5{,}280) \times 24(0.005 \times 15) \times 1.05}{9 \times 53} = \frac{99792}{477}$$

$$D = 209.2 \text{ ð } 210 \text{ drums}$$

ROAD MIX (Mixed-in-place Construction)

Road mix or mixed-in-place pavements are commonly constructed in the Theater of Operations. They may be surface courses, base courses, or subbase courses. As a surface, a road mix is normally suitable for medium or light traffic.

The principal advantage of mixing-in-place is that it uses aggregate already on the roadbed or airfield, or that which is available from nearby sources. Aggregates and asphalt can be mixed in place quickly with a minimum of equipment. However, central plant mixing (if mixing plants are available) gives better control, often at no increase in effort or time. Some features of mixed-in-place construction are:

- fair control of the moisture and volatile content through aeration with road-mixing equipment
- uniform coating and fair distribution of the asphalt on all aggregate surfaces.

Estimation for Road Mix

Estimates of aggregates required for road mix are identical to requirements for penetration of macadam pavement. The Modified Marshall Method should be employed for determining the amount of bitumen required. On the basis of experience, approximately 0.5 gallon per square yard of bitumen is required for each compacted inch of pavement. If a 1-inch finished pavement is to be placed, 0.5 gal/sq yd is the approximate rate of application for the bitumen. (The rate of application is based on the use of open-grade aggregate with a 1-inch maximum particle size.)

The formulas for a road-mix estimation are:

$$\text{Aggregate (AGG)} = \frac{L \times W}{9} \times \frac{FCT}{36} \times CF \times LF = LCY$$

$$\text{Binder} = \frac{L \times W}{9} \times (FCT \times AR_B) \times LF = \text{Gals.}$$

Example: The specifications and other data for a road-mix project are:

L = 1.1 miles(1.1 x 5,280 = 5,808 feet)

W = 24 feet

FCT = 2 inches

$$CF = 1.3 \qquad CF = \frac{2.6\ \text{(Loose thickness)}}{2\ \text{(Compacted thickness)}}$$

Rate of bitumen application 0.5 gal/sq yd/inch of final compacted thickness.

LF = 10 percent (or) 1.10 for aggregate

LF = 5 percent (or) 1.05 for binder

Find the drums of bitumen and loose cubic yards of aggregate needed for this job (53 gallons = 1 drum)

SOLUTION:

$$\text{Aggregate} = \frac{1.1 \times 5280 \times 24 \times 2 \times 2.6 \times 1.10}{648} = \frac{79732224}{648}$$

$$= 1230.4 \text{ ð } 1231 \text{ LCY}$$

$$\text{Binder} = \frac{1.1 \times 5280 \times 24 \times (2 \times 0.5) \times 1.05}{9} = 1626.4 \text{ ð } 1627 \text{ gallons}$$

$$\text{Drums} = \frac{16263 \text{ gallons}}{53 \text{ gallons}} = 306.8 \text{ ð } 307 \text{ drums}$$

TRAVEL PLANT MIX

Travel-plants are used only for road mixes, when you have more than 2 miles to do. The travel-plant mixing allows close control of the mixing operation. The proportion of the bituminous material and the aggregate, and the uniformity with which the two are mixed are of the greatest importance. In order to achieve a uniform product, several precautions must be taken:

- establish a uniform windrow of prepared material
- check carefully the uniformity of the gradation of the material in the windrow
- determine the proper amount of binder for mixing with the aggregate
- check that the road-mixing machine is in satisfactory operating condition.

Estimation for Plant Mix

To determine the total tonnage of plant mix required for a given paving area, the compacted volume in cubic feet is multiplied by the unit weight of the mix in pounds per cubic foot. Unit weight may be determined with the Marshall Method, as described previously. When the exact unit weight of a plant mix has not been determined, an estimated weight of 160 pounds per cubic foot may be used. (Unit weight is usually between 140 pounds and 160 pounds compacted cubic foot.) The formulas used for this method of plant mix are:

$$\frac{L \times W \times FCT}{12} \times UW = \text{Pounds} \qquad \frac{\text{Pounds}}{2000} = \text{Tons of Plant Mix}$$

Binder: tons of plant mix x OCA = Tons of AC

Aggregate: Tons of plant mix-tons of AC = Tons of Aggregate (AGG)

where:

L = length of paveed area in feet

W = width of paved area in feet

LF = loss factor, if it is known

FCT = final compacted thickness in inches or the depth of the pavement in inches after the completion of all compaction operations

UW = the exact unit weight of compacted plant mix in pounds per cubic foot

24,000 = 2000 x 12 or pounds per ton and inches per foot conversion factor

Example: A 2-inch thickness of plant mix is desired on a 110 foot by 650 foot parking lot. Find the tons of plant mix required for this project if the unit weight of plant mix is 147 pounds per cubic foot.

SOLUTION:

L = 650 feet

W = 10 feet

FCT = 2 inches

UW = 147 lb/cu ft

$$= \frac{650 \times 110 \times 2 \times 147}{24000} = 875.9 \text{ ó } 876 \text{ tons}$$

CONTINUOUS MIX PLANT

The amount of materials that are components of the plant mix can be determined best by a proportionate method. The job mix formula for this method is different. It is best demonstrated by the following example.

Example: The required tonnage of plant mix for a project is 800 tons. The aggregate blend is 50/40/10 (percentage course aggregate/fine aggregate/mineral filler). The bitumen content is 6 percent. How many tons of each aggregate are required?

Job mix formula is:

$$\frac{100 - OAC}{100} \times \% \text{ AGG} = \text{Adjusted \% of AGG.}$$

SOLUTION: Total aggregate percent by weight = 100 - 6 = 94 percent, or 0.94.
Coarse/aggregate = 0.94 x 50 percent = 47.0 percent by weight of the total mix.
Fine aggregate = 0.94 x 40 percent = 37.6 percent by weight of the total mix.
Mineral filler = 0.94 x 10 percent = 9.4 by weight of the total mix.

To convert to tons the required tonnage of plant mix is multiplied by the percentage of each component of the mix. The results should be adjusted so that the sum of the tonnage of components is equal to the required tonnage of plant mix.

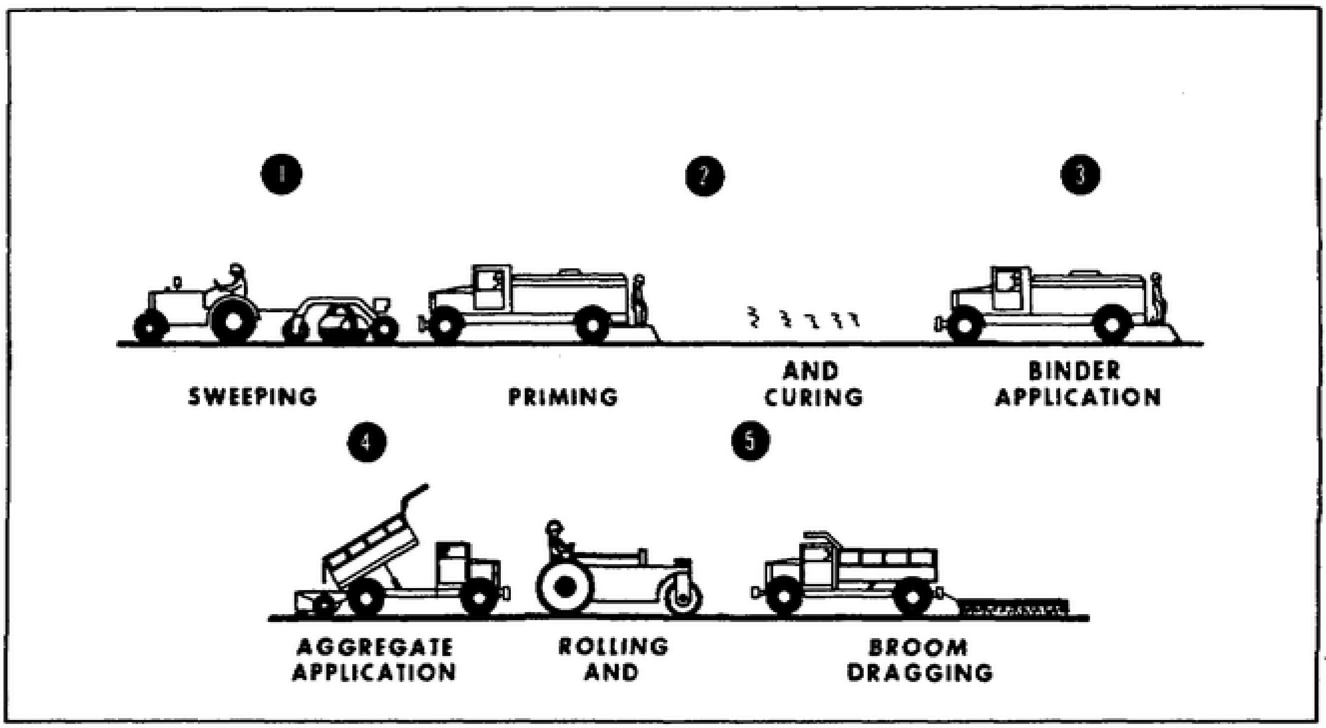
Coarse aggregate:	=	800 x 0.470	=	376.0 tons
Fine aggregate	=	800 x 0.376	=	300.8 tons
Mineral filler	=	800 x 0.094	=	75.2 tons
Bitumen	=	800 x 0.060	=	48.0 tons
				800.0

(The bitumen weight was calculated as a check.)

CONSTRUCTION SEQUENCE

The following diagrams illustrate the sequence of operations for priming or tack coating and for two types of road construction.

FIGURE 5. SEQUENCE OF OPERATIONS FOR SINGLE-PASS SURFACE TREATMENT ROAD CONSTRUCTION



Learning Event 2
EQUIPMENT UTILIZATION

Some of the many types of equipment used in pavement construction are listed below.

Hauling Equipment

Hauling equipment includes such items as the 5-ton and 20-ton dump trucks. An important thing to remember is that the truck must be kept clean.

Support Equipment

Support equipment includes such items as clamshells, belt conveyors, scoop loaders and dozers. Remember to keep these items in good working condition.

Asphalt Distributors (Bituminous Distributors)

This equipment is used primarily to spray bituminous material on a prepared surface. A tachometer registers the pump discharge in gallons per minute and a bitumeter shows the forward speed of the truck in feet per minute.

INSPECTING EQUIPMENT

Planning and managing the placement of bituminous surfaces present such varied conditions that it is impossible to establish hard and fast rules for all construction procedures. Also, there may be several equally good methods of arriving at the same desired result, and it would be unwise to restrict action to one specific line.

As a minimum you should check the following items of equipment to be used in placing bituminous materials:

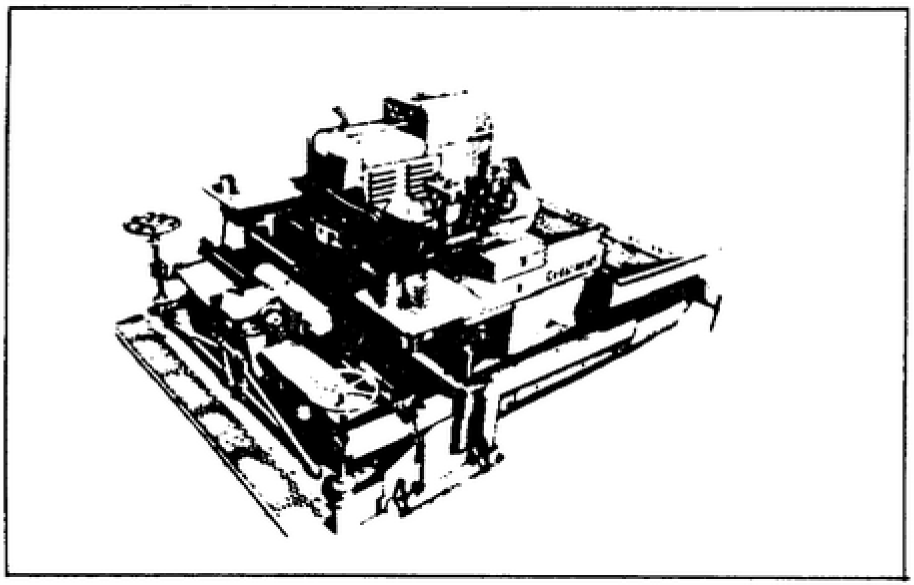
- Dump Trucks. Inspect the truck's dumping mechanisms and capability for carrying the materials, and insure that the dump bed is clean.
- Bituminous Distributor. Inspect all valves, pumps, burners, spray bars (nozzles), and tachometer and the bitumeter.
- Bituminous Paver. Inspect the rollers for pushing truck tires, hopper, treadway, spreader screws, tamper, screed, and depth adjustment controls.
- Rollers. Check the pneumatic tire pressure, scrapers, wheel moistening mechanism, and ballast.

Inspect each item of equipment using the TM for that equipment.

Asphalt Finishers (Bituminous Pavers)

This type of machine lays hot or cold bituminous mixtures into a smooth mat of the required thickness and width.

FIGURE 6. PAVER



Compaction Equipment

Compaction equipment includes such items as the two-axle tandem 9 to 14 ton roller (Figure 7), and the 9-wheel self propelled pneumatic-tired roller. Other types of compaction devices, such as hand tampers, can be used to compact inaccessible areas and patches.

FIGURE 7. 9- to 14-TON ROLLER

Aggregate Spreaders

Aggregate spreaders include such items as the standard hopper-type spreader, the nonstandard whirl type spreaders, and the self-propelled spreader.

Drag Boom

The drag boom is usually available through normal supply channels, but may be constructed in the field. Shop brooms and 3- by 6-inch timbers are the best expedient construction materials.

PRACTICE EXERCISE FOR LESSON 2

Instructions

Check your understanding of Lesson 2 by completing the practice exercise. There is only one correct answer to each question. Try to answer all of the questions without referring to the lesson materials.

When you have completed all of the questions, turn the page and check your answers against the correct responses. Each correct response is referenced to specific portions of the lesson material so that you can review any questions you have missed or do not understand, before continuing to the next lesson.

1. What are two types of pavement?

   a. hard and medium
   b. medium and fine
   c. road mix and hot plant mix
   d. bituminous material and binder material

2. What are the two types of preliminary treatments?

   a. bituminous coat and asphalt coat
   b. prime coat and tack coat
   c. aggregate coat and bituminous coat
   d. in-place coat and imported coat

3. What does travel plant mixing allow?

   a. faster mixing time
   b. batch mixing
   c. exact unit weight
   d. exact percentage of component mixing

4. Use the following information to determine the amount of aggregate in tons and the amount of binder in gallons required for a single surface treatment.

   Length of project .... 1/2 mile
   Width of project................................ 30 feet
   Rate of aggregate application............ 30 lbs/sq yd
   Loss factor (aggregate) .... 10 percent
   Los factor (binder) .... 5 percent

   a. 136 tons of aggregate and 2772 gallons of binder
   b. 146 tons of aggregate and 2772 gallons of binder
   c. 156 tons of aggregate and 7272 gallons of binder
   d. 166 tons of aggregate and 7272 gallons of binder

ANSWER SHEET FOR PRACTICE EXERCISE

Lesson 2	Learning Event
1. c	1
2. b.	1
3. a	1
4. b	1

Lesson 3

PLACEMENT OF BITUMINOUS SURFACES

TASK: Plan the placement of Bituminous Surfaces

CONDITIONS: Given this subcourse, a No. 2 pencil, a calculator (recommended) and an ACCP Examination Response Sheet

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75 percent of the examination questions.

CREDIT HOURS: 1

REFERENCES:

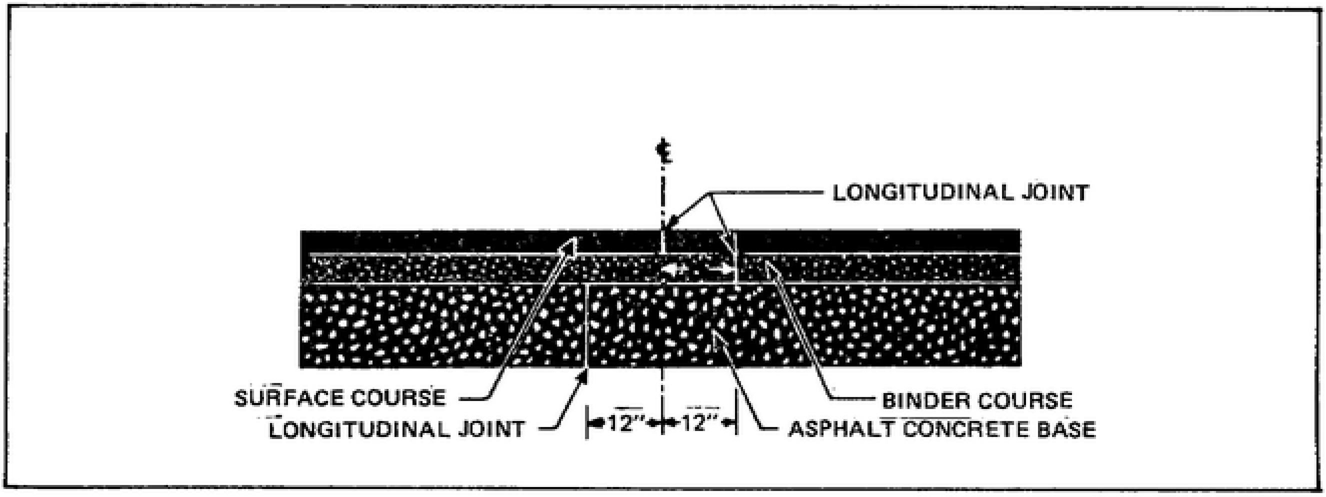
TM 5337, Paving and Surfacing Operations
TM 5-331D, Utilization of Engineer Construction Equipment
ST 5-330-8, Special Text, Flexible Pavements, February 1972.

Learning Event 1
PLACING AND SPREADING OF HOT MIX MATERIALS

PAVING OPERATION PLANNING

Before spreading with a paver, design a plan for placing the paving strips. Both binder and surface courses are to be laid so that the longitudinal joints are offset by at least one foot. Overlapping of successive courses (Figure 8) helps prevent a crack opening along a longitudinal joint.

FIGURE 8. OVERLAPPING OF SUCCESSIVE COURSES



You will need to make a general paving lane plan before laying any of the binder course in order to avoid problems with longitudinal joints in the surface course.

SPREADING HOT MIX MATERIALS

Pavements for Air Force bomber and fighter aircraft and modem high speed road traffic must be extremely smooth. Therefore, long wheelbase motor graders often are used for spreading both hot and cold asphalt plant mixes in base and leveling (binder) courses. The principal advantage of using the long wheelbase to lay the leveling course is the elimination of excessive humps, sags, and irregularities in the subgrade, base, or old pavement on which the mix is to be placed. Another benefit of laying a leveling course with a motor grader is a rough textured surface on which to place the surface course.

Do not attempt to spread with the motor grader unless the grader operator is highly skilled and experienced. An unskilled operator may do more damage than good.

Learning Event 2
ROLLING HOT MIX MATERIALS

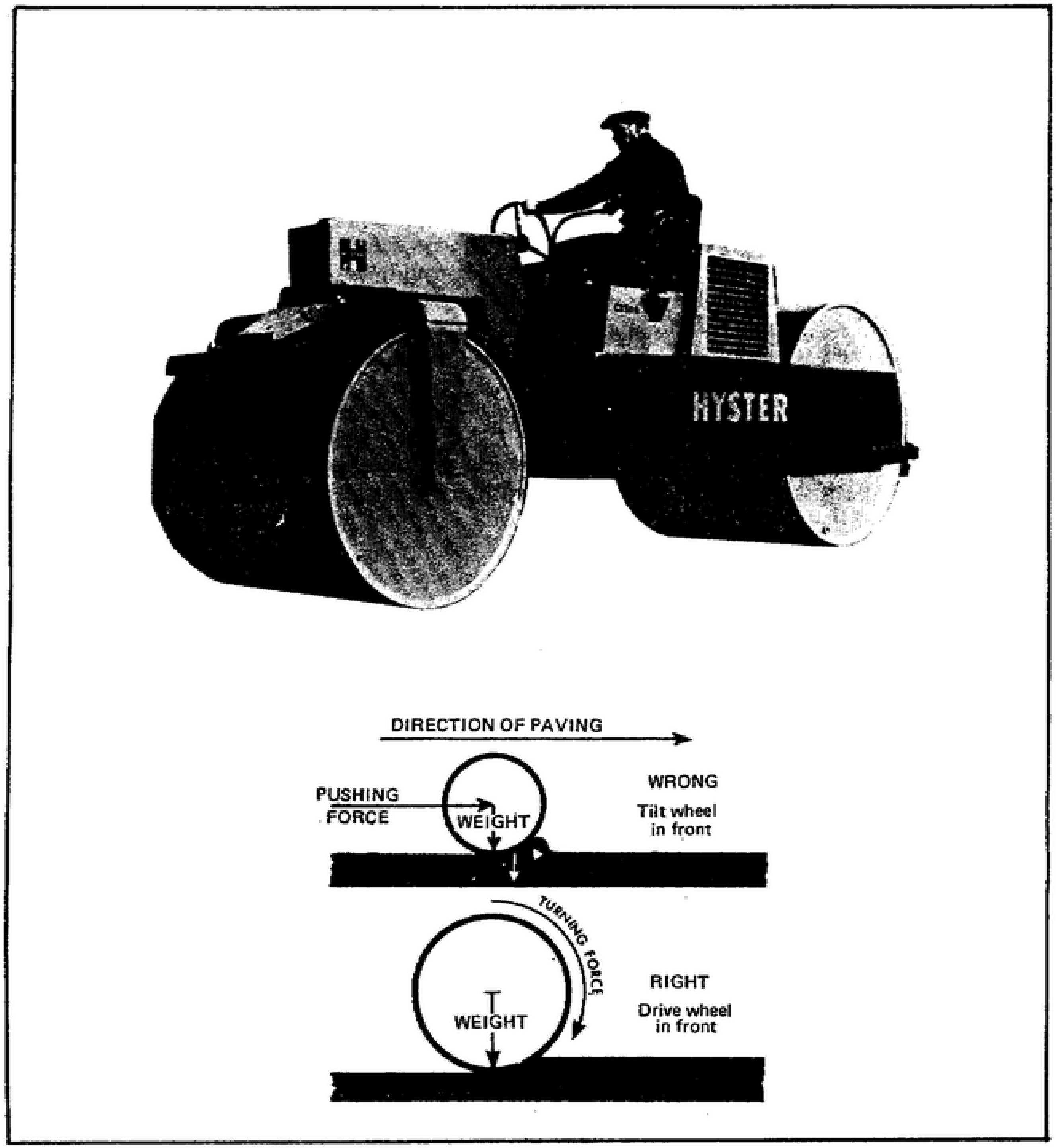
Most mixtures compact readily under rolling if spread at proper temperatures. Rolling should start as soon as possible after the material has been spread.

Rolling of the longitudinal joint should be done immediately behind the paving operation. The initial, or breakdown, pass with the steel roller (Figure 9) should be made as soon as it is possible to roll the mixture without cracking the mat or having the mix pick up on the roller wheels. The second, or intermediate rolling (9 wheel) should follow the breakdown rolling as closely as possible and should be done while the paving mix is still hot. The finish rolling (steel wheel) should be done while the material is still workable enough for removal of the roller marks. The following is suggested as a guide: longitudinal joint rolling directly behind the spreader; breakdown rolling less than 200 feet behind the spreader; second (intermediate) rolling 200 feet and more behind the breakdown rolling; finish rolling as soon as possible behind the second rolling.

If the specified density is not obtained during construction, subsequent traffic will further consolidate the pavement. This will cause rutting in the wheel paths. Use steel wheel rollers supplemented with pneumatic-tired rollers to obtain the required density.

ROLLING PROCEDURE

During rolling, the roller wheels should be kept moist with just enough water to avoid picking up the material. Rollers should move at a slow, uniform speed with the drive roller or wheels nearest the paver (Figure 9). Roller wheels should be kept clean at all times. The recommended maximum speed for rolling hot asphalt is 3 miles per hour.


HYSTER
DIRECTION OF PAVING
PUSHING FORCE
WEIGHT
WRONG
Tilt wheel in front
TURNING FORCE
WEIGHT
RIGHT
Drive wheel in front

Learning Event 3
INSPECTING AND TESTING MATERIAL

Close cooperation should be established between the road inspector and the plant inspector so that any change in the mixture can be made promptly. When possible, the road inspector and the plant inspector should frequently exchange visits. If he is familiar with plant operations, the road inspector can more easily determine if changes at the plant are necessary to improve the mix. The plant inspector, by becoming familiar with the paving operation, can better understand the problems of the road inspector.

Every truckload of material should be inspected as it arrives at the job site.

REASONS FOR REJECTION OF MIX

Reject a truckload of mix for these reasons:

- Too hot.
- Too cold.
- Excess coarse (AGG).
- Excess fine (AGG).
- Too much asphalt.
- Too little asphalt.
- Excess moisture.
- Not mixed uniformly.
- Contamination: oil, gas, trash, dirt...

Truckloads of mix that are contaminated will be rejected.

TESTING CONSTRUCTION

Density test samples should be taken and tests performed as often as conditions require, but at least once for every 400 tons of mix placed. To obtain a satisfactory specimen, the sample should be taken early in the morning when the pavement is cool. Any additional rolling required as a result of the tests should be done during the heat of the day.

A coring machine or a concrete saw may be used for cutting out the samples. Samples from a binder or surface course should be cut out approximately one foot square, completely through the thickness of the pavement, and removed carefully to avoid damage.

The specimen should be sent to the plant laboratory with proper identification.

If there is a nuclear densimeter, it may be used to check density.

INSPECTING SURFACES

Hot Mix

The chart shown below shows types of pavement imperfections and their probable causes.

TABLE 2. POSSIBLE CAUSES OF IMPERFECTIONS IN FINISHED PAVEMENTS

Insufficient or Non-Uniform Tack Coat	Improperly Cured Prime or Tack Coat	Mixture Too Coarse	Excess Fines in Mixture	Insufficient Asphalt	Excess Asphalt	Improperly Proportioned Mixture	Unsatisfactory Batches in Load	Excess Moisture in Mixture	Mixture Too Hot or Burned	Mixture Too Cold	Poor Spreader Operation	Spreader in Poor Condition	Inadequate Rolling	Over-Rolling	Rolling Mixture When Too Hot	Rolling Mixture When Too Cold	Roller Standing on Hot Pavement	Overweight Rollers	Excessive Moisture in Subsoil	Excessive Prime Coat or Tack Coat	Excessive Hand Raking	Labor Careless or Unskilled	Excessive Segregation in Laying	Operating Finishing Machine Too Fast	Types of Pavement Imperfections That May Be Encountered In Laying Plant-Mix Paving Mixtures.
					X	X	X													X					Bleeding
				X				X	X																Brown, Dead Appearance
					X	X	X													X			X		Rich or Fat Spots
		X	X			X	X			X	X	X	X	X	X	X					X	X	X	X	Poor Surface Texture
X	X	X				X	X			X	X	X	X		X	X	X	X			X	X	X	X	Rough Uneven Surface
		X		X		X	X			X	X	X	X			X					X	X	X		Honeycomb or Ravbling
		X								X	X	X	X		X	X					X	X	X		Uneven Joints
			X		X	X				X			X		X	X	X	X				X			Roller Marks
X	X		X		X	X	X	X			X	X			X			X			X				Pushing or Waves
			X	X		X								X	X			X	X						Cracking (Many Fine Cracks)
														X				X	X						Cracking (Large Long Cracks)
		X				X				X	X	X		X	X			X							Rocks Broken by Roller
		X		X		X			X	X	X	X											X	X	Tearing of Surface During Laying
X	X		X		X	X		X		X			X	X		X		X	X	X					Surface Slipping on Base

PRACTICE EXERCISE FOR LESSON 3

Instructions

Check your understanding of Lesson 3 by completing the practice exercise. There is only one correct answer to each question. Try to answer all of the questions without referring to the lesson materials.

When you have completed all of the questions, turn the page and check your answers against the correct responses. Each correct response is referenced to specific portions of the lesson material so that you can review any questions you have missed or do not understand, before continuing to the next lesson.

1. How soon should rolling operations start after the material has been spread?

   a. within the first hour
   b. within the first two hours
   c. anytime the same day
   d. as soon as possible

2. What is the recommended maximum speed for rolling hot asphalt?

   a. 1 MPH
   b. 2 MPH
   c. 3 MPH
   d. 4 MPH

3. With whom should the road inspector maintain close cooperation?

   a. plant inspector
   b. truck drivers
   c. paver operators
   d. vehicle inspector

4. How many truckloads of material should be inspected by the road inspector?

   a. every other one
   b. every one
   c. every third one
   d. one out often

ANSWER SHEET FOR PRACTICE EXERCISE

Lesson 3	Learning Event
1. d	2
2. c	2
3. a	3
4. b	3

Lesson 4
TIME REQUIREMENT FOR HOT MIX PLANT PLACEMENT

TASK: Estimate the time required for hot mix plant placement.

CONDITIONS: Given this subcourse, a No. 2 pencil, a calculator (recommended) and a ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75 percent of the examination questions.

CREDIT HOURS: 2

REFERENCES:
TM 5-337, Paving and Surfacing Operations
TM 5-331D, Utilization of Engineer Construction Equipment
ST 5-330-8, Special Text, Flexible Pavements, February 1972.

Learning Event 1
DURATION OF HOT PLANT MIX PAVING JOBS

INTRODUCTION

When constructing a road or airfield pavement, it is necessary for you to be able to estimate the duration of the hot plant mix paving operation. In this lesson, you will learn how to make these estimates and determine the capabilities of laydown and maintenance equipment.

This production estimating technique is useful when paving roads in the Theater of Operations. Normally, estimating the production or duration of such a hot plant mix paving job is simply a matter of calculating the number of tons of mix per 1" of lift per paver that the plant can produce and then looking up the paving width and paving speed on the paving chart. Then, it is necessary to determine how many passes you will have to make and multiply the number of passes by the paving distance. The number of hours necessary to complete the job is determined by dividing the answer obtained (number of passes x paving distance) by the paving speed times sixty (60).

$$\frac{\text{Plant Output}}{\text{\# of Pavers}} = \text{Tons per Paver}$$

$$\frac{\text{Tons per Paver}}{\text{Lift Thickness}} = \text{Tons per 1'' Lift}$$

$$\frac{\text{Distance \& \# of Passes}}{\text{Paving Speed x 60}} = \text{Hours}$$

NOTE: Pavers traveling at the same time = One Pass.

The result is the duration of paving operations, assuming no breakdowns or stopping due to weather. However, a problem occurs when the number of trucks committed to haul the mix is restricted-as often is the case in the Theater of Operations. When paving close to the plant there is very little travel time between plant and paver and few trucks are required. When paving further from the plant more trucks are required. Otherwise, the plant and paving operations must be slowed to keep pace with the haul capability of a fixed number of trucks.

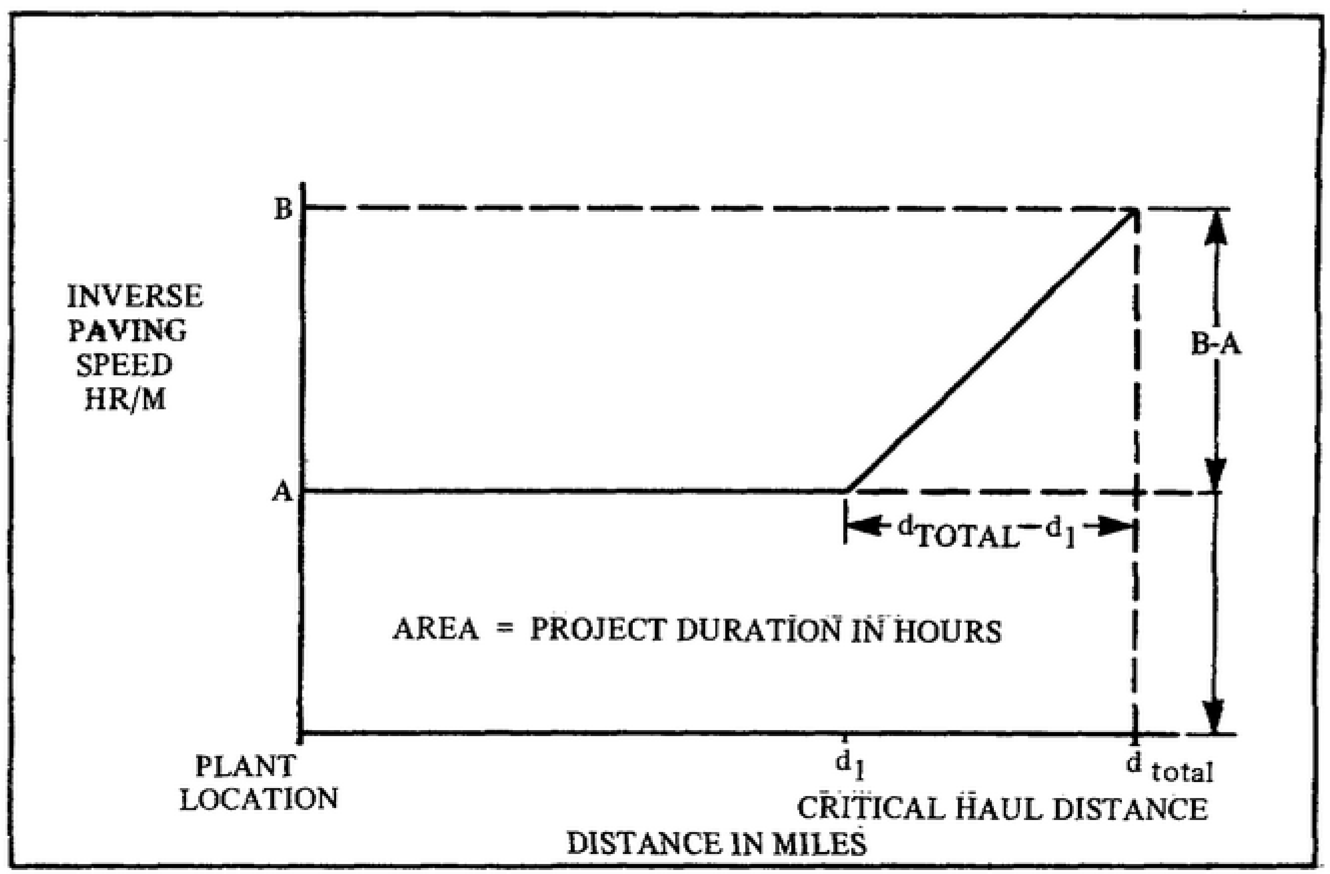
Before trying to calculate the duration of such a project, some assumptions must be defined. First, we will assume that the paving begins dose to the plant and moves away. Second, we will assume that there are a fixed number of trucks available to support the project. If somewhere along our paving project, the combined haul capability of these trucks falls below the output of the plant (the paver can always keep up with the TOE Army plant), the operation must slow to match the haul capacity of the trucks. Third, we will assume that it takes approximately the same amount of time to load a truck at the plant as it will take to off-load the truck at the paver. This is reason-

able when one considers that the plant should run continuously in order to produce high quality pavement. The paver can only place the mix as fast as deliveries are made to it. It should not stop and start in order to make high quality plant mix pavement. Therefore, the output of the plant, laydown rate of the paver, and truck delivery rate should all be matched.

This concept is somewhat unconventional and not widely practiced in Army paving operations in the past. If it is applied, however, both production and paving operations will improve immensely by avoiding starting and stopping the plant during one period of production.

Figure 10 is a graph of the inverse of the paver speed in miles per hour versus the distance the paver is from the plant. It is assumed that there is a fixed number of trucks hauling plant mix. Between zero miles and d miles from the plant, the inverse speed remains constant. The trucks are able to haul plant mix at the maximum plant output. Beyond dl the trucks are not able to haul at a rate that will keep up with the maximum plant output. Each mile that the paver moves away from the plant results in a diminished delivery rate to the paver and, consequently, a higher inverse paver speed in hours per mile. Point A represents the inverse paver speed between the plant and d miles down the road. Point B represents the inverse paver speed at the end of the paving project, d_{total} (the maximum distance from the

FIGURE 10. PRODUCTION ESTIMATION GRAPH



plant). The area under this line is the total hours of paving required from the plant to a point d_{total} miles from the plant. If we calculate the values for A, B, and d_1 we can easily find this area by geometry.

The inverse paving speed (A) between the plant and d_1 is calculated using the following equation:

$$A = \frac{(.22) \times W \times FCT \times UW}{M}$$

A = Inverse paving speed in hours/mile

W = Width of the paving in feet

FCT = Thickness of the paving in inches

UW = Unit weight of the paving material in pounds/cubic foot

M = Maximum plant output in tons/hour

The constant .22 is for conversion of units.

The distance d_1 is calculated using the following equation:

$$d_1 = \frac{(N-2) \times S \times D}{2 \times M}$$

d_1 = Distance in miles from the plant to where the inverse paving speed starts to increase

N = Number of trucks available for hauling

S = Average travel speed of the trucks in miles/hour

D = Dump size of each truck in tons

M = Maximum plant output in tons/hour

The inverse paving speed (B) at the end of the project is calculated using the following equation:

$$B = \frac{A \times dtotal}{d_1}$$

B = Inverse paving speed at the end of the project in hours/mile

A = Inverse paving speed from the plant to d_1

d_1 = Distance in miles from the plant to where the inverse paving speed starts to increase

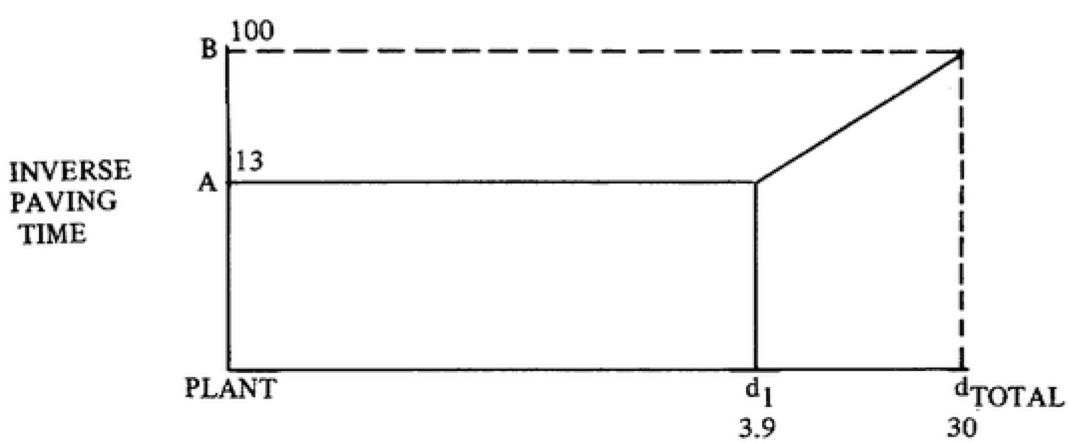
d_{total} = Distance in miles from the plant to the end of the paving project

Now, knowing the values for A, B, d_1 and d_{total}, we can calculate the total paving time. As stated earlier, the total paving time is equal to the area under the line of the graph (Figure 10). The area under the line can be divided into two areas: a rectangle and a triangle. In Figure 10, the rectangle has a height of A and a length of d_{tota1}. The triangle has a base of (d_{total} - d_1) and a height of (B - A). The area of a rectangle is equal to height times length and the area of a triangle is equal to one-half times the base times height. Thus, the area under the line is:

$$\text{Paving Time (Area)} = A \times d_{total} + 1/2(d_{total} - d_1)(B - A)$$

Example: Assume that you are about to pave a 3D-mile stretch of road starting at the plant. The road is to be paved 20 feet wide and 2.5 inches thick. The plant produces 135 tons of mix per hour at a unit weight of 160 pounds per cubic foot. You are using nine trucks traveling at an average speed of 15 miles per hour. Each truck has a dump size of 10 tons (see Figure 11).

FIGURE 11. INVERSE PAVING TIME



From the information given we know d_{total} is 30 miles and A, d_1, and B can be calculated as follows:

$$A = \frac{.22 \times 20 \times 2.5 \times 160}{135} = \frac{1760}{135} = 13 \text{ hours/mile}$$

$$d_1 = \frac{(9 - 2) \times 15 \times 10}{2 \times 135} = \frac{1050}{270} = 3.9 \text{ miles}$$

$$B = \frac{13 \times 30}{3.9} = 100 \text{ hours/mile}$$

With this information we can then calculate the paving times as follows:

Paving Time = (13 x 30) + [1/2 x (30 - 3.9) x (100 - 13)]
= 390 + 1135.35 = 1525.35 hours.

Learning Event 2
CAPABILITIES OF LAYDOWN AND MAINTENANCE EQUIPMENT

The capabilities and specifications for laydown and maintenance equipment used in road and airfield construction are found in TM 5-337 and TM 5-331D. Some of the equipment used is listed below.

Rotary Sweeper

The rotary sweeper is used to remove the dust from the surface of the existing pavements prior to paving.

Asphalt Distributor*

The asphalt distributor is a truck-mounted unit consisting of a 1500 gallon tank, an open flame heating system, an asphalt pump, a low pressure air blower, and a circulating and spraying system.

Asphalt Finisher

The asphalt finisher receives hot or cold bituminous- mix and places it to the desired thickness and cross section.

Asphalt Kettle, 165 Gallon

The asphalt kettle is used primarily in patching and maintenance operations.

***NOTE: Extreme caution must be exercised while heating asphalt to prevent fire and explosion damage to equipment.**

PRACTICE EXERCISE FOR LESSON 4

Instructions

Check your understanding of Lemon 4 by completing the practice exercise. There is only one correct answer to each question. Try to answer all of the questions without referring to the lesson materials.

When you have completed all of the questions, turn the page and check your answers against the correct responses. Each correct response is referenced to specific portions of the lesson material so that you can review any questions you have missed or do not understand, before continuing to the next lesson.

1. Your unit has been given the mission of paving 30 miles of road 22 feet wide. One two-inch lift of asphalt concrete is to be placed, and maximum plant output is 200 tons/hour at a unit weight of 150 lbs/cubic foot. You have ten 20-ton dump trucks available and one SA35 paver. You are to begin paving at the plant. Road speed for the trucks is 30 MPH. What is the distance from the plant where the inverse paver speed starts to increase (d_1) ?

    a. 12 miles
    b. 18miles
    c. 22 miles
    d. 28 miles

2. How many hours will it take to pave this project assuming no loss of time?

    a. 622 hours
    b. 425 hours
    c. 316 hours
    d. 262 hours

3. What is the purpose of using the rotary sweeper?

    a. to level the pavement
    b. to remove excess aggregate
    c. to remove dust
    d. to remove water from the surface

4. What size tank is mounted on the asphalt distributor?

    a. 800 gallons
    b. 1000 gallons
    c. 1200 gallons.
    d. 1500 gallons

5. What type bituminous mix is placed in the asphalt finisher?

   a. hot or cold
   b. bituminous or aggregate
   c. binder or aggregate
   d. wet or dry

6. What may happen to the asphalt kettle while heating asphalt and not exercising extreme caution?

   a. The asphalt becomes too hot.
   b. The tank will overflow.
   c. The kettle will shift and overflow.
   d. There will be a fire or explosion.

ANSWER SHEET FOR PRACTICE EXERCISE

Lesson 4	Learning Event
1. a	1
2. c	1
3. c	2
4. d	2
5. a	2
6. d	2

Lesson 5
AGGREGATE SPECIFICATIONS OF BITUMINOUS HOT MIX OPERATIONS

TASK: Determine the Required Aggregate Gradation Specifications for Bituminous Surfacing Operations

CONDITIONS: Given this subcourse, a No. 2 pencil, a calculator (recommended) and an ACCP Examination Response Sheet

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75 percent of the examination questions.

CREDIT HOURS: 2

REFERENCES:
TM 5-337, Paving and Surfacing Operations
ST 5-330-8, Special Test, Flexible Pavements

Learning Event 1
GRADATION SPECIFICATIONS

The Corps of Engineers has established tables for gradation specification limits for bituminous pavements. Selecting a gradation specification is based on the following:

- Use of the Mix: surface course, binder course, road-mix, etc.
- Type of Binder: asphalt cement, or tar
- Tire pressure: high pressure (over 100 psi) or low pressure (100 psi and under)
- Maximum Size of Aggregate: based on maximum size of material in stockpiles or maximum size based on thickness of pavement course to be placed. Maximum size for surface course placed with mechanical spreader is one-half the thickness of the surface course. Maximum size for binder course placed with mechanical spreader is two-thirds the thickness of the binder course with a maximum of 1 1/2 inch.

The tables for gradation specification limits for bituminous pavements are listed below. The tables show the gradation specification limits based on the maximum size of aggregate. The six tables cover the following conditions:

Table	Type of Binder	Use of Mix	Tire Pressure
3	Asphalt Mixture	Surface Course	Low Pressure
4	Asphalt Mixture	Surface Course	High Pressure
5	Asphalt Mixture	Binder Course	High and Low Pressure
6	Tar Mixture	Surface Course	Low Pressure
7	Tar Mixture	Binder Course	High and Low Pressure
8	Bituminous Road-mix	Surface Course	N/A

The selection of the aggregate specification is based on the requirements that the type of binder is to be an asphalt cement, for a surface course, and for low pressure tires, as shown in Tables 3 through 8, following. A study of the sieve analysis of materials in the stockpiles indicates that the maximum size aggregate is 3/4 inch, as the course aggregate his 100% passing the 3/4 inch sieve.

TABLE 3

GRADATION SPECIFICATION LIMITS FOR BITUMINOUS PAVEMENTS ASPHALT MIXTURE–SURFACE COURSE–LOW PRESSURE TIRES (100 psi AND UNDER)

Percent Passing (By Weight)

Sieve Size	1 1/2 inch Maximum Gradation 1			1 inch Maximum Gradation 2			3/4 inch Maximum Gradation 3		
	A	B	C	A	B	C	A	B	C
1 1/2"	100	100	100	---	---	---	---	---	---
1"	79-95	83-96	86-98	100	100	100	---	---	---
3/4"	70-84	74-86	78-90	80-95	84-96	90-98	100	100	100
1/2"	61-75	66-79	71-84	68-86	74-89	79-93	80-95	84-96	87-98
3/8"	54-68	60-72	65-78	60-77	66-82	72-87	72-86	76-88	80-92
#4	42-54	48-60	54-66	45-60	52-68	60-75	55-70	61-74	67-80
#8	33-45	39-51	45-57	34-49	41-57	49-64	43-57	49-62	56-68
#16	26-37	31-42	37-48	26-40	33-47	40-54	34-46	39-51	46-57
#30	19-29	23-33	29-38	19-30	25-37	30-43	26-36	30-40	36-46
#50	14-22	17-25	21-29	14-23	18-28	21-32	18-27	21-30	26-34
#100	8-14	10-16	13-19	8-16	11-18	13-21	10-17	13-20	16-22
#200	3-6	3.5-6.5	4-7	3-7	3.5-7.5	4-8	3-7	3.5-7.5	4-8

Percent Passing (By Weight)

Sieve Size	1/2 inch Maximum Gradation 4			3/8 inch Maximum Gradation 5		
	A	B	C	A	B	C
1 1/2"	---	---	---	---	---	---
1"	---	---	---	---	---	---
3/4"	---	---	---	---	---	---
1/2"	100	100	100	---	---	---
3/8"	79-94	81-95	85-96	100	100	100
#4	59-73	64-80	72-85	75-95	78-95	80-95
#8	46-60	53-67	60-73	60-79	63-83	66-86
#16	36-49	42-54	48-60	46-65	49-68	52-72
#30	28-38	32-42	37-48	33-51	36-54	38-58
#50	19-28	22-30	26-35	21-37	24-40	26-43
#100	11-18	13-20	16-22	12-24	14-26	16-28
#200	4-8	4-8	4-8	5-9	6-10	7-11

TABLE 4

GRADATION SPECIFICATION LIMIT FOR BITUMINOUS PAVEMENTS
ASHPHALT MIXTURE–SURFACE COURSE–*HIGH PRESSURE TIRES
(Over 100 psi)

Percent Passing (By Weight)

Sieve Size	1½ inch Maximum	1 inch Maximum Gradation 6			3/4 inch Maximum Gradation 7		
		A	B	C	A	B	C
1"		100	–	–	–	–	–
3/4"		86-97	–	–	100	–	–
1/2"		76-90	–	–	82-96	–	–
3/8"		69-83	–	–	75-90	–	–
#4		55-70	–	–	60-73	–	–
#8		45-59	–	–	46-60	–	–
#16		35-48	–	–	34-48	–	–
#30		26-38	–	–	24-38	–	–
#50		17-29	–	–	15-28	–	–
#100		10-20	–	–	8-17	–	–
#200		3-6	–	–	3-6	–	–

*Optional for Low Pressure Tires (100 psi and under)

TABLE 5

Percent Passing (By Weight)

Sieve Size	3/4 inch Maximum Gradation 11			1/2 inch Maximum Gradation 12		
	A	B	C	A	B	C
2"	–	–	–	–	–	–
1½"	–	–	–	–	–	–
1"	–	–	–	–	–	–
3/4"	100	100	100	–	–	–
1/2"	70-95	74-95	77-95	100	100	100
5/8"	60-80	64-84	68-88	71-95	75-95	78-95
#4	42-60	47-65	52-70	50-71	54-75	59-80
#8	30-49	36-54	39-57	36-56	40-60	45-66
#16	23-39	27-43	29-46	26-44	29-48	34-52
#30	17-30	19-33	22-36	19-34	22-37	25-40
#50	12-23	13-24	15-26	13-25	15-27	17-29
#100	6-16	8-17	9-18	9-18	10-19	11-19
#200	3-7	3-7	3-7	4-9	4-9	4-9

TABLE 6

GRADATION SPECIFICATION LIMITS FOR BITUMINOUS PAVEMENTS
TAR MIXUTR–SURFACE COURSE–LOW PRESSURE TIRES
(100 psi and under)

Percent Passing (By Weight)

Sieve Size	1 inch Maximum Gradation 13			3/4 inch Maximum Gradation 14			1/2 inch Maximum Gradation 15		
	A	B	C	A	B	C	A	B	C
1"	100	100	100	–	–	–	–	–	–
3/4"	78-95	80-95	84-96	100	100	100	–	–	–
1/2"	68-85	71-88	75-90	76-95	80-95	85-96	100	100	100
3/8"	57-75	62-82	66-85	67-85	73-89	79-93	75-95	80-95	86-96
#4	40-58	47-65	52-70	50-66	58-73	65-80	55-70	63-80	70-84
#8	28-46	35-51	40-58	38-53	43-58	53-68	38-54	48-64	54-69
#16	20-35	26-40	30-47	28-41	32-46	41-55	27-41	36-49	41-55
#30	13-25	18-30	22-36	19-30	23-36	29-42	18-29	24-36	28-42
#50	8-17	12-21	15-26	12-21	15-25	18-29	10-20	15-25	19-29
#100	4-12	7-14	9-18	6-14	9-16	11-18	6-13	9-17	11-19
#200	2-8	4-10	4-10	4-10	4-10	6-10	4-10	4-10	6-10

TABLE 7

GRADATION SPECIFICATIONS FOR BITUMINOUS PAVEMENTS TAR MIXTURE – BINDER COURSE – HIGH & LOW PRESSURE TIRES

Percent Passing (By Weight)

SEIVE SIZE	1 1/2 INCH MAXIMUM Gradation 16		
	A	B	C
1 1/2"	100		
1"	70 – 95		
3/4"	56 – 84		
1/2"	44 – 75		
3/8"	36 – 65		
#4	20 – 45		
#8	12 – 33		
#16	6 – 23		
#30	2 – 15		
#50	0 – 8		
#100	0 – 4		

TABLE 8

GRADATION SPECIFICATION LIMIT FOR BITUMINOUS PAVEMENTS BITUMINOUS ROAD MIX – SURFACE COURSE

Percent Passing (By Weight)

Sieve Size	1 inch Maximum Gradation 17			3/4 inch Maximum Gradation 18			1/2 inch Maximum Gradation 19		
	A	B	C	A	B	C	A	B	C
1"	100			–			–		
3/4"	85-100			100			–		
1/2"	72-95			82-100			100		
3/8"	61-90			68-93			82-100		
#4	43-79			48-82			57-88		
#8	32-68			35-71			41-76		
#16	24-56			26-60			30-64		
#30	18-44			20-48			22-52		
#50	13-32			14-38			15-40		
#100	9-21			10-25			10-26		
#200	5-21			5-12			5-12		

Learning Event 2
PROPER BLENDING METHODS

TRIAL AND ERROR METHOD OF AGGREGATE BLENDING

The features of the trial and error method are very simple but it may require-several trials to meet the specified gradation selected. The information required is:

- Sieve analysis of each stockpile.
- Specified gradation of blend (gradation selected).
- Quantity of materials available.

The example problem below illustrates this method.

EXAMPLE

Requirements

Determine an acceptable aggregate blend for a hot-plant asphalt concrete mix, surface course for an airfield, low pressure tires.

Situation

Materials for the mix are in stockpiles and are in ample quantities. The materials consist of coarse aggregate, fine aggregate, fine river bar sand (FRB), and limestone dust (LSD). The washed sieve analyses of stockpiled materials are shown on lines 1, 2, 3, and 4 of Figure 12.

Selection of Proper Aggregate Gradation

The first step in the trial and error method is to select the proper aggregate gradation from the gradation tables. The selection of the aggregate specification is based on the requirements of asphalt cement binder for a surface course and for low pressure tires. The sieve analysis of materials in the stock piles indicates that the maximum size aggregate is 3/4-inch (100 percent passes the 3/4-inch sieve). With all of this information a study is made of the aggregate specifications listed in the table. The gradation meeting the requirements is gradation #3. Next it is necessary to select either gradation 3a, 3b, or 3c. Gradation A has more coarse AGG; Gradation C has more fine AGG, and Gradation B has a good mixture of both.

FIGURE 12

BITUMINOUS MIX DESIGN - AGGREGATE BLENDING

PROJECT	DATE
FOR INSTRUCTIONAL PURPOSES ONLY	JOB/AGGREGATE GRADATION NUMBER 3C

GRADATION OF MATERIAL

SIEVE SIZE (To be entered by Technician): →	3/4	1/2	3/8	#4	#8	#16	#30	#50	#100	#200		
MATERIAL USED	PERCENT PASSING											
Coarse Agg (CA)	100	70	34	3	0	0	0	0	0	0		
Fine Agg (FA)	100	100	100	90	72	52	36	21	10	3		
Fine River Bar Sand (FRB)	100	100	100	100	100	100	100	94	72	10		
Limestone Dust (LSD)	100	100	100	100	100	100	100	100	98	90		
DESIRED:	100	87/98	80/92	67/80	56/68	46/57	36/46	26/34	16/22	4/8		

COMBINED GRADATION FOR BLEND - TRIAL NUMBER #1

SIEVE SIZE (To be entered by Technician): →	% USED	3/4	1/2	3/8	#4	#8	#16	#30	#50	#100	#200		
MATERIAL USED	% USED	PERCENT PASSING											
(CA)	37	37	25.9	12.6	1.1	0	0	0	0	0	0		
(FA)	50	50	50	50	45	36	26	18	10.5	5	1.5		
(FRB)	10	10	10	10	10	10	10	10	9.4	7.2	1.0		
(LSD)	3	3	3	3	3	3	3	3	3	2.9	2.7		
BLEND:		100	88.9	75.6	59.1	49	39	31	22.9	15.1	5.2		
DESIRED:		100	87/98	80/92	67/80	56/68	46/57	36/46	26/34	16/22	4/8		

COMBINED GRADATION FOR BLEND - TRIAL NUMBER #2

SIEVE SIZE (To be entered by Technician): →	% USED	3/4	1/2	3/8	#4	#8	#16	#30	#50	#100	#200		
MATERIAL USED	% USED	PERCENT PASSING											
CA	27	27	18.9	9.2	.8	0	0	0	0	0	0		
FA	50	50	50	50	45	36	26	18	10.5	5	1.5		
FRB	20	20	20	20	20	20	20	20	18.8	14.4	2		
LSD	3	3	3	3	3	3	3	3	3	2.9	2.7		
BLEND:		100	91.9	82.2	68.8	59	49	41	32.3	22.3	6.2		
DESIRED:		100	87/98	80/92	67/80	56/68	46/57	36/46	26/34	16/22	4/8		

DD FORM 1217, DEC 65 — PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

FIGURE 12A

BITUMINOUS MIX DESIGN - AGGREGATE BI[illegible]DING

PROJECT	FOR INSTRUCTIONAL PURPOSES ONLY	DATE
		AGGREGATE GRADATION NUMBER

GRADATION OF MATERIAL

SIEVE SIZE (To be entered by Technician): →	3/4	1/2	3/8	#4	#8	#16	#30	#50	#100	#200		
MATERIAL USED	PERCENT PASSING											
COURSE AGG (CA)	100	70	34	3	0	0	0	0	0	0		
FINE AGG (FA)	100	100	100	90	72	52	36	21	10	3		
FINE RIVER BAR SAND (FRBS)	100	100	100	100	100	100	100	94	72	10		
MINERAL FILLER (MF)	100	100	100	100	100	100	100	100	98	90		
DESIRED:	100	87/98	80/92	67/80	56/68	46/57	36/46	26/34	16/22	4/8		

COMBINED GRADATION FOR BLEND - TRIAL NUMBER #3

SIEVE SIZE (To be entered by Technician): →		3/4	1/2	3/8	#4	#8	#16	#30	#50	#100	#200		
MATERIAL USED	% USED	PERCENT PASSING											
CA	28	28	19.6	9.5	.8	0	0	0	0	0	0		
FA	50	50	50	50	45	36	26	18	10.5	5	1.5		
FRB	19	19	19	19	19	19	19	19	17.9	13.7	1.9		
LSD	3	3	3	3	3	3	3	3	3	2.9	2.7		
BLEND:		100	91.6	81.5	67.8	58	48	40	31.4	21.6	6.1		
DESIRED:		100	87/98	80/92	67/80	56/69	46/57	36/46	24/34	16/22	4/8		

COMBINED GRADATION FOR BLEND - TRIAL NUMBER

SIEVE SIZE (To be entered by Technician): →													
MATERIAL USED	% USED	PERCENT PASSING											
BLEND:													
DESIRED:													

Estimate Percentage by Weight of Aggregates

The next step in Trial No. 1 is to estimate the percentages by weight of each of the aggregates to be combined to meet the "desired" gradation. The "desired" line indicates that 4 - 8 percent is desired passing the #200 sieve. A study of the gradation of the materials shows that the LSD has 90 percent pausing and the FRB has 10 percent passing the #200 sieve. If 3 percent of LSD were used, the percent passing the #200 sieve for this material would be 2.7 percent (3% x 90% = 2.7%). If 10 percent of FRB was used, the percent passing of this material through the #200 sieve would be 1 percent (10% x 10% = 1%), making a total for these two materials in the final blend of 3.7 percent.

Since the fine material has 3 percent passing the #200 sieve, it is evident additional material will pass the #200 sieve from the fine aggregate, making the total passing the #200 sieve near the desired 4 - 8 percent. This would require in the neighborhood of 50 percent of fine material (50% x 3% = 1.5%). This 1.5 percent plus the 3.7 percent from the other two materials would give a total of 5.2 percent. However, all other requirements for the various sieve sizes must also be met. For the first trial, try percentages of 3 percent LSD, 10 percent FRB, 50 percent fine, and the balance of 37 percent coarse aggregate. Enter these percentages in the proper spaces under column "Percent Used" for Trial No. 1 as shown in the chart.

Multiply the Percentages

The next step is to multiply all percentages of materials passing each size sieve by those percentage figures. Enter the results in the proper spaces on the chart. The percentages calculated passing each sieve should then be totaled and entered on the "Blend" line.

Check the Blend

Check the blend against the "Desired." The blend percentages passing sieves of 3/8-inch through #200 are less than the "Desired." The blend percentage passing the 1/2- and 3/4-inch through #200 sieve are correct, indicating that the selection of percentages of FRB and LSD is about correct. This leaves the selection of obtaining additional material passing the 3/8-inch through #100 sieves to the fine river bar sand.

Trial No. 1

In Trial No. 2, as shown in the chart, the percentages chosen are 27 percent coarse, 20 percent FRB (an increase of 10 percent for FRB and a decrease of 10 percent for coarse), and the same percentages as before for the FA and LSD. The resulting blend using these percentages is shown in Figure 12. When compared with the requirements of "Desired," it is very near the ideal. It is now possible to state in trial no. 3 that our blend is 28/50/19/3,

that is 28 percent coarse, 50 percent fine, 19 percent FRB, and 3 percent LSD (mineral filler).

Total Mix Weight

The percentage of aggregates -28/58/19/3-that were determined by the trial and error method in the example problem make up the total aggregate weight. Bituminous material (binder) must be added to the aggregate to obtain the total mix weight. The binder material is listed as a percentage of the total mix weight. Assume that the percent binder as determined by the design procedure was 6 percent by weight of a total mix. The weight of the aggregate then becomes 100%-6 and/or 94% of the total mix weight.

It is necessary to adjust the percentages of the aggregate to a percentage by weight of the total mix weight as follows:

Coarse Aggregate	–	28% x 94%	=	26.3%
Fine Aggregate	–	50% x 94%	=	47.0%
Fine River Bar Sand	–	19% x 94%	=	17.9%
Limestone Dust	–	3% x 94%	=	2.8%
Bituminous Material (Binder)	–		=	6.0%
		TOTAL		100%

The job mix formula is then 26.3 percent CA, 47.4 percent FA, 17.9 percent FRB, 2.8 percent LSD, and 6 percent bituminous material.

It is now possible to advise the operator at the mixing plant of the percentages or actual weights of each ingredient that is to be combined in the mix. This is the next step in mix design. It is outlined in Learning Event 3.

Learning Event 3

THE MARSHALL STABILITY METHOD: DETERMINATION OF OPTIMUM BITUMINOUS CONTENT

The Marshall method presented here is applicable to all bituminous paving mixtures. The Marshall method may be used for design of tar and tar-rubber mixes.

Investigation work has indicated that the "optimum" asphalt content is one of the most important factor in the proper design of an asphaltic paving mixture. Extensive research in pavement behavior studies has resulted in the establishment of criteria for determining the optimum asphalt content for a given blend of aggregates.

The Marshall method consists of the determination of five Marshall properties from test specimens that have been prepared by definite procedures and specifications. The test properties are described below.

Stability

The stability of the test specimens is the maximum load resistance in pounds which the standard test specimens will develop at 140°F when tested as outlined hereinafter.

Unit Weight

The unit weight of the compacted specimens is expressed as pounds per cubic foot. Unit weight is obtained by multiplying the specific gravity of the specimens by the unit weight of water (62.4 pounds per cubic foot).

Flow

The flow value is the total movement or strain, in units of 1/100 inch occur ring in the specimens between no load and maximum.

Percent Voids Total Mix

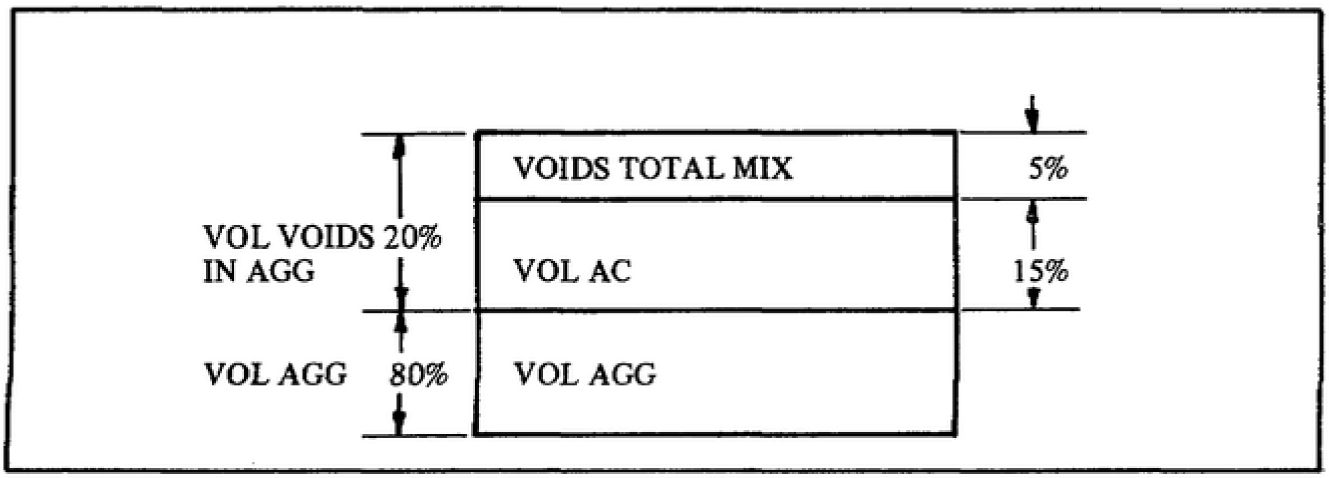
This is the ratio of the volume of voids in the compacted specimens to the total volume of the specimens expressed as a percentage. Experience has indicated that a compacted completed asphalt concrete pavement must contain air voids to allow expansion space for the asphalt on hot summer days and for anticipated future compaction by traffic. If the asphalt has no place to go within the pavement, the pavement will "bleed," that is, free asphalt will appear on the surface causing a slick condition and reducing the stability of the pavement. A pavement reduced to 1 percent voids may bleed. The recommended percentage is between 3 and 5 percent for surface courses and between 4 and 6 percent for binder courses for low pressure tires and between 5 and 7 percent for binder courses for high pressure tires.

Percent Voids Filed with Asphalt

The percent voids filled with asphalt is the ratio between the volume of asphalt in the mix and the volume of voids in the aggregate expressed in percent.

Example. Refer to Figure 13. Assume 20 percent of the volume of the specimen is the volume of the voids in the aggregate. Fifteen percent of the total volume of the specimen is filled with asphalt (assuming 5 percent voids total mix). Therefore, 15/20 x 100 = 75 percent of the total voids are filled with asphalt Generally for surface course the percent voids filled should be between 70 and 80 percent.

FIGURE 13. PERCENT VOIDS FILLED WITH ASPHALT



$$\% \text{ Voids Filled with AC} = \frac{\text{Vol AC}}{\text{Vol Voids in AGG}} \times 100 \; \frac{15}{20} \times 100 = 75\%$$

DETERMINING THE OPTIMUM ASPHALT CONTENT (OAC)

Test specimens are prepared with at least five different asphalt contents. The values of the Marshall properties are determined from these samples. The values are then plotted on graphs (Figures 14 - 17). The graphs and criterion tables (9 and 10) are then used to determine the optimum asphalt content (OAC).

The following provides an example of the use of the graphs to determine the OAC. The mix is for a surface course, high pressure tires, and an AGG water absorption rate of less than 2%.

TABLE 9

MARSHALL TEST SPECIFICATIONS WITH ASTM APPARENT SPECIFIC GRAVITY
(Aggregate Blends Showing Water Absorption up to 2½%

(1) PROPERTY	(2) COURSE	(3) CRITERIA (75 Blows) ***HIGH PRESS	(50 Blows) LOW PRESS	(4) DETERMINATION OF OAC HIGH PRESS	LOW PRESS
Stability	Surface	1800 or higher	500 or higher	Peak of curve	Peak of Curve
Unit Wt	Surface	---	---	Peak of Curve	Peak of Curve
Flow	Surface	16 or less	20 or less	Not Used	Not Used
% Voids Total Mix	Surface	3% - 5%	3% - 5%	4%	4%
% Voids Filled w/AC	Surface	70% - 80%	75% - 85%	75%	80%
Stability	Binder	1800 or higher	500 or higher	Peak of Curve*	Peak of Curve*
Unit Wt	Binder	---	---	Peak of Curve*	Peak of Curve*
Flow	Binder	16 or less	20 or less	Not Used	Not Used
% Voids Total Mix	Binder	5% - 7%	4% - 6%	6%	5%
% Voids Filled w/AC	Binder	50% - 70%	65% - 75%	60%*	70%*
Stability	Sand Asphalt	**	500 or higher	**	Peak of Curve
Unit Wt	Sand Asphalt	---	---	**	Peak of Curve
Flow	Sand Asphalt	**	20 or less	Not Used	Not Used
% Voids Total Mix	Sand Asphalt	**	5% - 7%	**	6%
% Voids Filled w/AC	Sand Asphalt	**	65% - 75%	**	70%

(5).

*If the inclusion of bitumen contents at these points in the average causes the voids total mix to fall outside the limits, then the optimum bitumen content should be adjusted so the voids total mix are within the limits.

**Criteria for sand asphalt to be used in designing pavements for high-pressure tires have not been established.

***High pressure tires are those above 100 psi. Low pressure tires are those with 100 psi and under.

TABLE 10

MARSHALL TEST PROPERTIES WITH BULK IMPREGNATED SPECIFIC GRAVITY
(Aggregate Blends Showing Water Absorption Greater Than 2½%

(1) PROPERTY	(2) COURSE	(3) CRITERIA		(4) DETERMINATION OF OAC	
		(75 Blows) ***HIGH PRESS	(50 Blows) LOW PRESS	HIGH PRESS	LOW PRESS
Stability	Surface	1800 or higher	500 or higher	Peak of Curve	Peak of Curve
Unit Wt	Surface	---	---	Peak of Curve	Peak of Curve
Flow	Surface	16 or less	20 or less	Not Used	Not Used
% Voids Total Mix	Surface	2% - 4%	2% - 4%	3%	3%
% Voids Filled w/AC	Surface	75% - 85%	80% - 90%	80%	85%
Stability	Binder	1800 or higher	500 or higher	Peak of Curve*	Peak of Curve*
Unit Wt	Binder	---	---	Peak of Curve*	Peak of Curve*
Flow	Binder	16 or less	20 or less	Not Used	Not Used
% Voids Total Mix	Binder	4% - 6%	3% - 5%	5%	4%
% Voids Filled w/AC	Binder	55% - 75%	70% - 80%	65%	75%
Stability	Sand Asphalt	**	500 or higher	**	Peak of Curve
Unit Wt	Sand Asphalt	---	---	**	Peak of Curve
Flow	Sand Asphalt	**	20 or less	Not Used	Not Used
% Voids Total Mix	Sand Asphalt	**	4% - 6%	**	5%
% Voids Filled w/AC	Sand Asphalt	**	70% - 80%	**	75%

(5)*

*If the inclusion of bitumen contents at these points in the average causes the voids total mix to fall outside the limits, then the optimum bitumen should be adjusted so that the voids total mix are within the limits.

**Criteria for sand asphalt to be used in designing pavement for high pressure tires have not been established.

***High pressure tires are those above 100 psi. Low pressure tires are those with 100 psi or under.

Step 1

Determine the percentage asphalt content (AC) for each Marshall property. Go to Table 9, column 4, High Pressure, to find where to enter the graph.

Stability. The percentage AC for stability is determined by the peak of the curve. From the peak of the curve a vertical line is drawn down to the percent AC line. In this case the reading for maximum stability is approximately 4.3 percent (Figure 14).

Unit Weight. The percent AC for unit weight is determined by the peak of the curve. From the peak of the curve a vertical line is drawn down to the percent AC line. Figure 15 shows that the reading for maximum unit weight in this case is 4.5 percent.

FIGURE 14

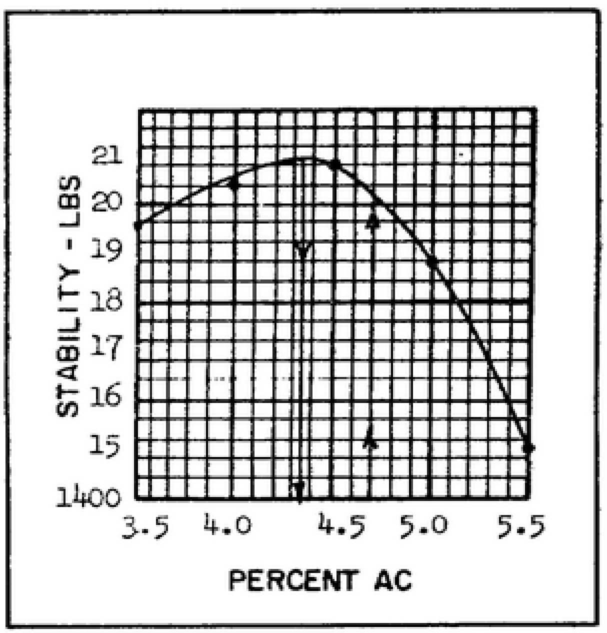
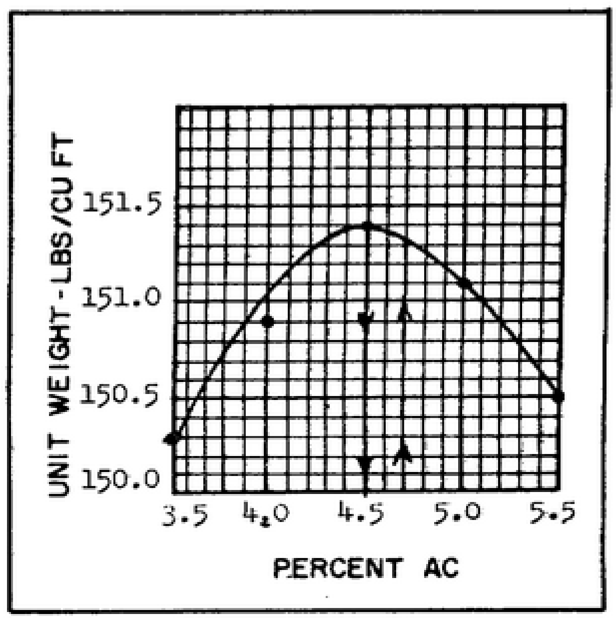


FIGURE 15



Percent Voids Total Mix. In Figure 16, the percent voids total mix is 4 per cent. Percent voids total mix curve is entered at the left at 4 percent, and a horizontal line is drawn to the right to intersect the curve. From this inter section, a line is drawn vertically down to the percent AC line, where AC is found to be 5 percent.

Percent Voids filled with AC. Figure 17 shows the percent voids filled with AC is 75 percent. Thus, the curve is entered at the left at 75 percent and a horizontal line is drawn to the right to intersect the curve and down to the percent AC line. In this example the value is 4.9 percent AC.

FIGURE 16

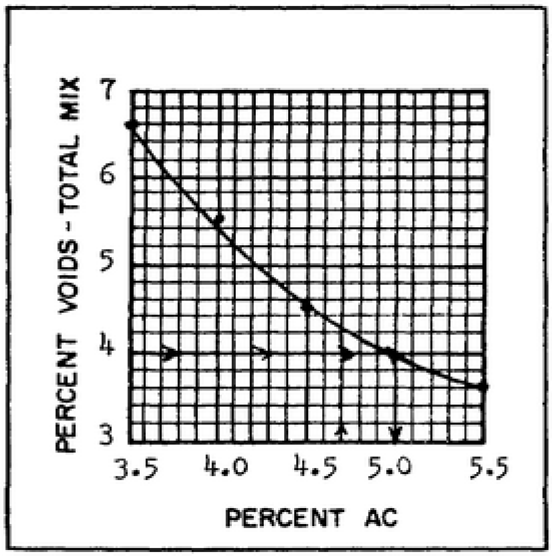
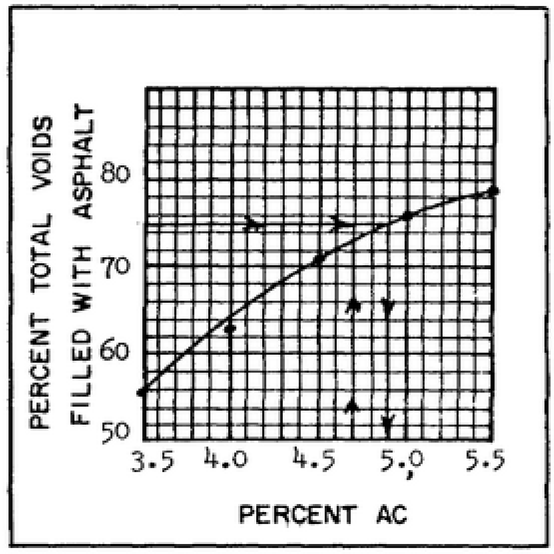


FIGURE 17



Step 2

Percentage asphalt content for the properties are then tabulated:

Peak of Stability	4.3%
Peak of Unit-Weight	4.5%
4% Voids in Total Mix	5.0%
75% Total Voids Filled with AC	4.9%

and an average of the four obtained: 18.7% ÷ 4 = 4.7. (Trial optimum asphalt content).

Step 3

In this step you check the trial OAC value to see that the criteria given in column 3 of Table 9 are met. This is done by entering all five of the curves at the Trial OAC, 4.7 percent, and drawing vertical lines up to intersect the curves.

Stability. Entering this curve at 4.7 percent, the value of stability is read at approximately 2000 pounds, which meets the requirement of 1800 pounds or higher as given in column 3 of Table 9.

Unit Weight. Table 9 indicates there is no definite criteria for the unit weight. This is because various types of aggregate would give various unit weights in the compacted mix. However, the unit weight is used as a factor in the determination of the optimum asphalt content. In this case, on entering the unit weight curve, the unit weight at 4.7 percent (OAC) is 151.35 pounds per cubic foot. On a contract job, this should be determined with great care as the contractor will be held to a certain percentage of this value as the required density in the final compacted pavement.

Percent Voids Total Mix. Checking back into this curve at 4.7 percent, the value of OAC is about 4.2 percent, which is within the allowable range of 3 to 5 percent.

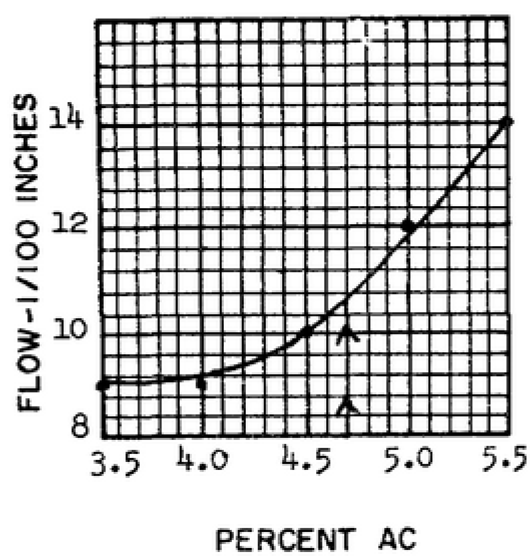
Percent Voids Filled with AC. Checking back into this curve at 4.7 percent, it is found that the value is about 72 percent, which is within the limits of 70 to 80 percent.

Step 4, Flow

In the example, using the value of 4.7 percent asphalt, as OAC, the curve shows an expected flow of approximately 11. This is below the maximum criterion of 16 for surface course for high pressure tires as given in column 3 of Table 9.

Since all1 criteria have been met, the asphalt content of the mix being used as an example is considered to be 4.7 percent asphalt based on the weight of the total mix (Figure 18).

FIGURE 18



JOB MIX FORMULA

Once the optimum asphalt value has been selected, it is necessary to set up the "Job-mix Formula," This is nothing more than a statement of the percentages of the total mix weight of each of the ingredients in the mix.

In the example shown below, it is assumed that the aggregate blend is:

Coarse Aggregate	-	53 percent
Fine Aggregate	-	42 percent
Mineral Filler	-	5 percent

The OAC was determined as 4.7 percent of the total mix weight. Thus, to determine the percentages of each size aggregate of the total mix weight, it is necessary to multiply each of the given percentages by 95.3 percent (100% - 4.7%; total percent of aggregate by weight in the mix) as follows:

Coarse Aggregate	–	53 x 95.3	=	50.5%
Fine Aggregate	–	42 x 95.3	=	40.0%
Mineral Aggregate	–	5.0 x 95.3	=	4.8%
				95.3%
Asphalt Cement	–			4.7%
		Total Mix	=	100.0%

The job-mix formula then is: CA 50.5%, FA 40.0%, MF 4.8%, and AC 4.7%.

PRACTICE EXERCISE FOR LESSON 5

Instructions

Check your understanding of Lesson 5 by completing the practice exercise. There is only one correct answer to each question. Try to answer all of the questions without referring to the lesson materials.

When you have completed all of the questions, turn the page and check your answers against the correct responses. Each correct response is referenced to specific portions of the lesson material so that you can review any questions you have missed or do not understand, before continuing to the next lesson.

1. What are the three types of aggregate based on particle size?

   a. light, medium, and heavy
   b. coarse, fine, and mineral filler
   c. dry, wet, and open gradation
   d. uniform, macadam, and dense

2. How many types of aggregate gradations are there?

   a. 1
   b. 2
   c. 3
   d. 4

3. The selection of the gradation specification is based on

   a. use of the mix and type of binder.
   b. thickness of the surface and type of spreader
   c. type of spreader and use of the asphalt
   d. thickness of the binder and the type of asphalt distributor

4. The maximum size of aggregate based on

   a. type of surface and condition of base course
   b. location of pavement, and type of equipment available
   c. maximum size in stockpiles and thickness of pavement course
   d. maximum surface course placed with a mechanical spreader and type binder

5. What action is taken when the selected blend does not meet the desired blend?

   a. redesign the desired blend
   b. conduct another trial
   c. select additional coarse aggregate
   d. add a larger percent of binder

6. Using the information below, determine the trial optimum asphalt content for a surface course.

Peak of Stability	4.5 percent
Peak of Unit Weight	4.6 percent
Voids in Total Mix	5.1 percent
Total Voids Filled with AC	4.9 percent

   a. 4.6 percent
   b. 4.8 percent
   c. 5.0 percent
   d. 5.8 percent

7. Using the information below, determine the job-mix formula.

Coarse Aggregate	47.0 percent
Fine Aggregate	46.0 percent
Mineral Filler	7.0 percent
OAC	4.8 percent

   a. CA 45.7%, FA 42.8%, MF 5.7%, and AC 5.8%
   b. CA 43.7%, FA 44.8%, MF 7.7%, and AC 3.8%
   c. CA 43.7%, FA 42.8%, MF 7.7%, and AC 5.8%
   d. CA 44.7%, FA 43.8%, MF 6.7%, and AC 4.8%

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ANSWER SHEET FOR PRACTICE EXERCISE

Lesson 5	Learning Event
1. b	1
2. d	1
3. a	1
4. c	1
5. b	2
6. b	3
7. d	3

Lesson 6
OPERATIONS OF A HOT MIX PLANT

TASK: Plan the Operations of a Hot Mix Plant

CONDITIONS: Given this subcourse, a No. 2 pencil, a calculator (recommended) and an ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75 percent of the examination questions.

CREDIT HOURS: 1

REFERENCES:

TM 5-337, Paving and Surfacing Operations
TM 5-331D, Utilization of Engineer Construction Equipment
ST 5-330-8, Special Text, Flexible Pavements

Learning Event 1
PLANT SITE SELECTION

INTRODUCTION

The site selection for a hot mix plant is an important part of your duties. To prevent delays in the road or airfield construction, the plant must be located so that it is close to the project and to the materials needed for that project. Travel time to and from the plant must be held to a minimum.

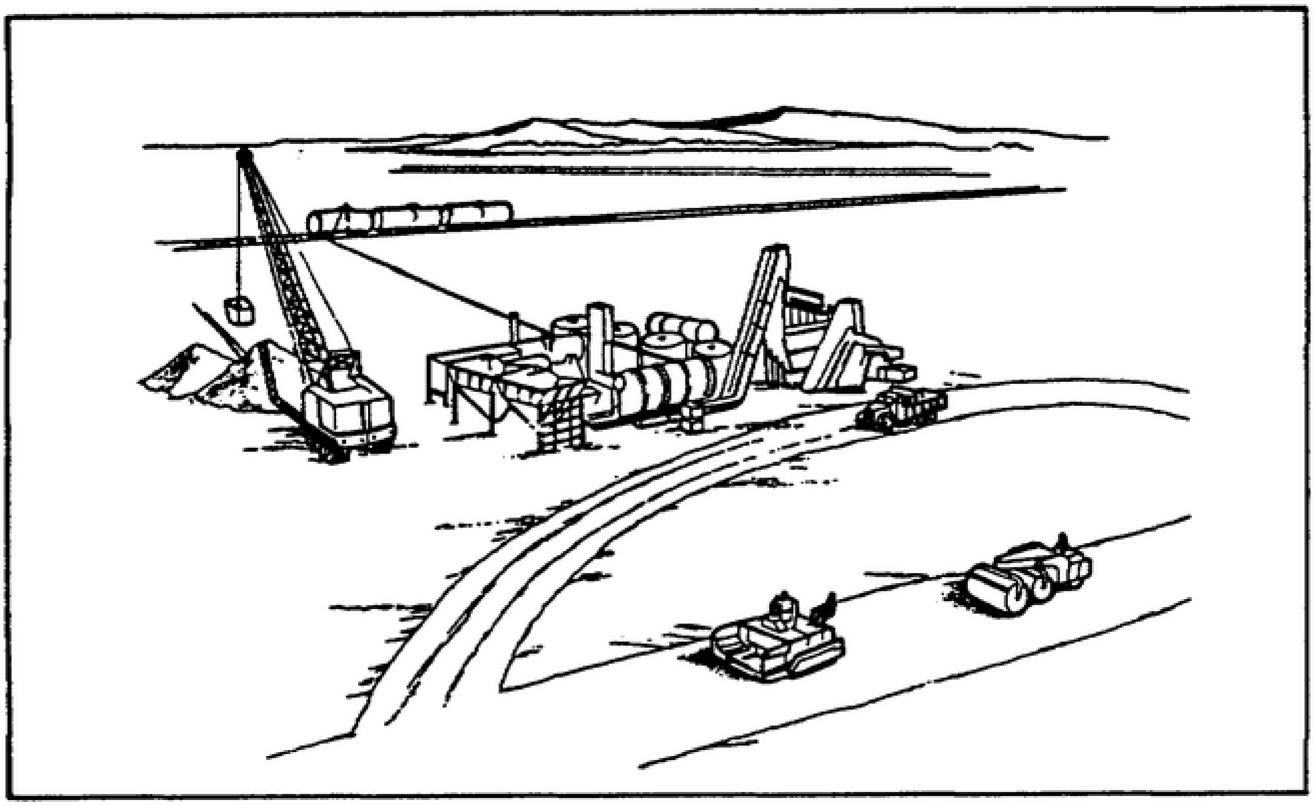
A central plant should be located between the source of aggregate and asphalt and the site of the project. Ton-mileage for hauling the mix components and the mix itself are computed and optimized. The minimum laying temperature of the mix will limit the distance it can be transported, depending on the speed of the hauling equipment, the rapidity of bitumen cooling, the maximum allowable mixer temperature, and weather conditions. Normally, mixes can be moved up to 50 miles in a temperate climate. The plant location should also have a good roadnet.

A central plant should be sited in a well-drained area with stable soil. The site must provide room to maneuver equipment and stockpiled materials, and space to store drummed asphalt. Asphalt should be stored at a safe distance from the plant in order to reduce the fire hazard.

A side hill location will improve drainage, and also will reduce the explosion hazard associated with loading trucks in a pit. However, the plant must be on a level foundation to insure maximum stability, facilitate alignment, and prevent wear of the plant components. Should it be necessary to locate the plant on a level site, the loading pit should be as large as possible to allow for maximum ventilation. Also, prevailing winds should be identified to prevent dust from contaminating populated areas.

Figure 19 illustrates a typical location of an asphalt plant with respect to the job site.

FIGURE 19



Learning Event 2
TYPES OF PLANTS AND COMPONENTS

CENTRAL MIX PLANT

A central mix plant is an assembly of specialized equipment that produces paving mixtures of aggregate and bituminous material. The central mix plants in the Army are portable, wheel-mounted, self-contained units. Portability, combined with ease of operation and maintenance, permits widespread use of all plants in a variety of situations.

There are two principal sizes of central mix plants, the 100 to 150 ton per hour (TPH) plant and the 80 to 120 TPH plant.

MIX PLANT-CLASSIFICATION

An asphalt mix plant is placed in one of three classifications depending on the precision with which aggregate sizes can be proportioned in mixing.

- High Type. The high type plant, also known as a multiple aggregate plant, produces mix suitable for construction of heavy-duty wearing surfaces.
- Intermediate Type. The intermediate type plant, also known as a single aggregate plant, is capable of producing mix normally adequate for laydown of wearing surfaces for average traffic conditions.
- Soil Stabilization. The soil stabilization (or soil treatment) plant can produce material for uses ranging from base courses to light duty wearing surfaces.

The component units of typical stabilization, intermediate and high type mix plants are:

- For a soil stabilization plant
  - aggregate feeder system (usually a belt conveyor)
  - surge hopper
  - cold elevator
  - asphalt mixer
- For an intermediate type plant
  - aggregate hopper
  - cold elevator
  - aggregate dryer
  - dust control unit
  - fines feeder
  - one or two hot elevators
  - single bin feeder
  - asphalt mixer

- For a high type plant
  - partitioned aggregate hopper
  - cold elevator
  - aggregate dryer
  - dust control unit
  - hot elevators
  - gradation control unit
  - fines feeder
  - asphalt mixer

Procedures, specifications, and characteristics of the equipment and components are found in TM 5-331D.

Learning Event 3
SUPPORT EQUIPMENT

Each type of asphalt plant requires several items of equipment to support its operations Some of the items of support equipment are listed below.

SUPPORT EQUIPMENT FOR A 100 TO 150 TPH CENTRAL MIX PLANT

- Hot oil heater with 15 KW gen
- Asphalt melter
- Piping set
- Four-bin cold feeder
- Cold elavator
- Aggregate dryer
- Dust collector
- Hot elevator
- Gradation control unit
- Single aggregate feeder
- Fines feeder
- Asphalt mixer
- Hot oil heater
- Dedrumming equipment
- Storage tanks
- Pumping equipment

Specifications and purposes of the components shown above re listed in TM 5-331D.

Learning Event 4
PLANT CALIBRATION AND OUTPUT

A necessary step in the production of asphalt mixes is the calibration of the mixing plant. During the calibration process the components of the plant are adjusted to feed the proper amounts of aggregate and asphalt cement to meet the mix specifications.

The following list contains essential preliminary information for plant calibrations:

- Mix specifications limits
  - percent and type of bitumen
  - aggregate gradation limits
- Gradation of the available aggregates
- Number of bins to be used for dry aggregate
- Screen sizes available
- Aggregate moisture content

The recommended sequence in calibrating the high type asphalt plant is as follows:

- Determine the proper aggregate blend.
- Select the screen sizes to be used in the gradation unit.
- Determine the dryer capacity.
- Determine the smallest screen size capacity.
- Determine the plant output.
- Determine the feeding rate.
- Determine the gradation unit feeder speeds.
- Calibrate the gradation unit feeder gates.
- Calibrate the fines feeder.
- Calibrate the asphalt metering pump.
- Determine the initial cold feed settings.
- Check all settings.

The procedures for calibrating the above items are:

Step 1. Determine the Proper Aggregate Blend

There are various methods used for determining the aggregate blend proportions. To date, however, the trial and error method is most workable for field engineers. The procedures for this method of blending was discussed in Lesson 5, Learning Event 2. The information required is a sieve analysis performed on each stockpile of aggregate, as specified gradation of blend (gradation selected), and the quantity of materials available (Table 12).

TABLE 12. AGGREGATE BLENDING

CONCRETE/BITUMINOUS MIX DESIGN - AGGREGATE

Job No.:	Project:	Date:

Gradation of Material

Sieve Size	% Used	1"	3/4"	1/2"	3/8"	#4	#8	#50	#200
		Sieve Size - Percent Passing							
COARSE AGG		100	72	46	33	12	2	0	0
FINE AGG		100	100	98	94	75	54	2	0
SAND		100	100	100	100	100	98	58	3
MIN FILLER		100	100	100	100	100	100	98	90
SPECIFICATIONS		100	80/95	68/86	60/77	45/60	34/48	14/23	3/7

Combined Gradation for Blend - Trial No. 1

Sieve Size	% Used	1"	3/4"	1/2"	3/8"	#4	#8	#50	#200
		Sieve Size - Percent Passing							
CA	45	45.0	32.4	20.7	14.9	5.4	0.9	0	0
FA	25	25.0	25.0	24.5	23.5	18.8	13.5	0.5	0
S	25	25.0	25.0	25.0	25.0	25.0	24.5	14.5	0.8
M.F.	5	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.5
Blend		100.0	87.4	75.2	68.4	54.2	43.9	19.9	5.3
Desired		100.0	87.5	72.0	68.5	52.5	41.5	18.5	5.0

Combined Gradation for Blend - Trial No. 2

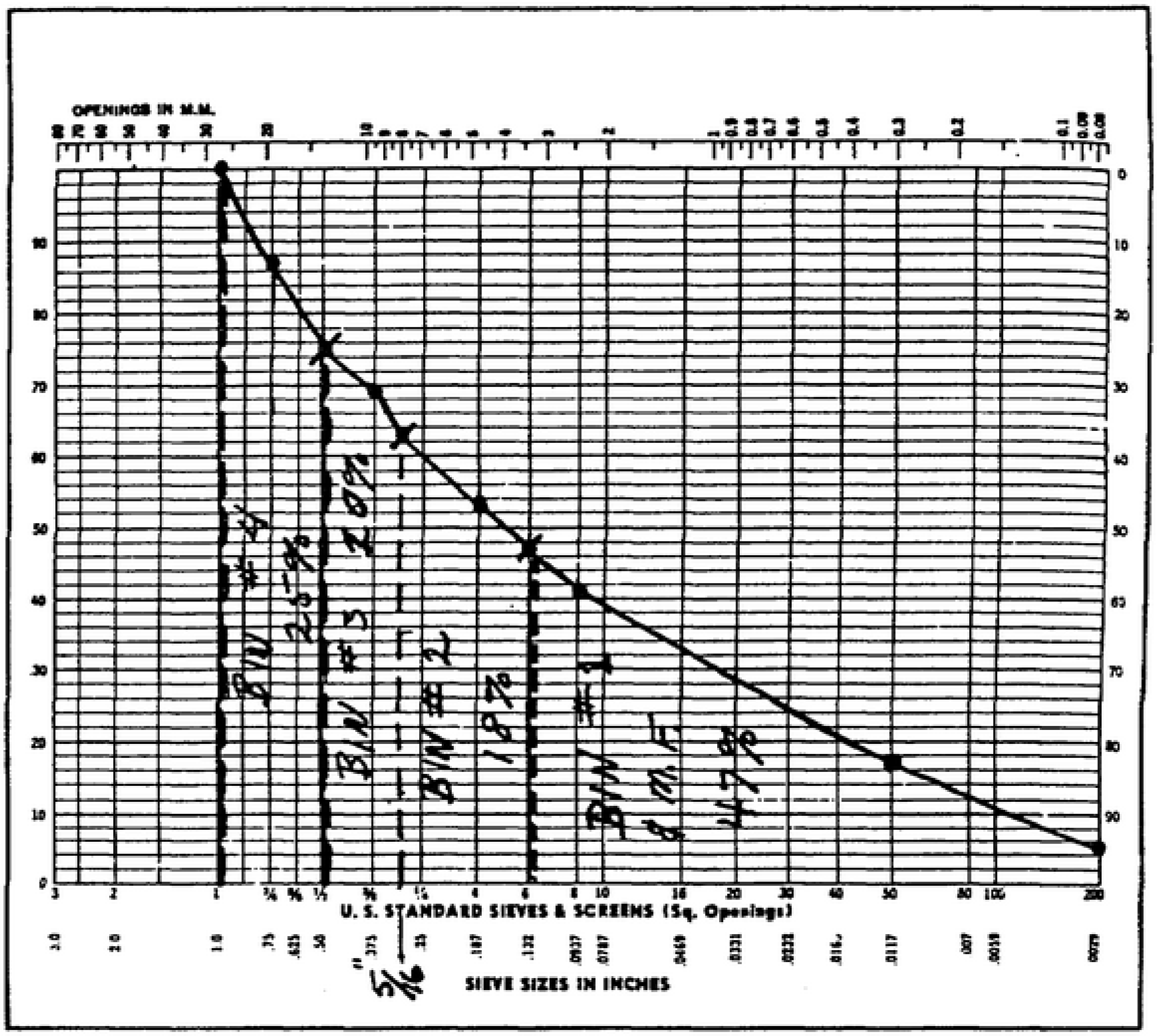
Sieve Size	% Used	1"	3/4"	1/2"	3/8"	#4	#8	#50	#200
		Sieve Size - Percent Passing							
C.A.	45	45.0	32.4	20.7	14.9	5.4	0.9	0	0
F.A.	30	30.0	30.0	29.4	28.2	22.5	16.2	0.6	0
S.	20	20.0	20.0	20.0	20.0	20.0	19.6	11.6	0.6
M.F.	5	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.5
Blend		100.0	87.4	75.1	68.1	52.9	41.7	19.1	5.1
Desired		100.0	87.5	77.0	68.5	52.5	41.8	18.5	5.0

REMARKS: FOR INSTRUCTIONAL PURPOSES ONLY

Step 2. Select the Screen Sizes to be Used in the Gradation Unit.

- Use of gradation curve. The results of the aggregate blending operation are graphed on the aggregate chart (Figure 20).

FIGURE 20. CONCRETE/BITUMINOUS MIX DESIGN-AGGREGATE



The curve formed by the graph is an indication of aggregate gradation balance and the resulting mix stability. The curve also assists in determining the aggregate to be proportioned into each gradation unit, bin, and the selection of screen sizes. The curve is plotted on a standard gradation chart having vertical lines which represent the aggregate, or sieve, sizes and horizontal lines to designate the percent of aggregate passing each sieve size. The gradation curve is cumulated from 0% to 100% in 2% increments, showing a passing and retained gradation. The curve that Is plotted depicts the desired ag-

gregate gradation after all aggregates and mineral filler entering the plant are blended together.

- Selecting bin separations. The number of fractions into which the aggregate is to be separated I established by specifications and depends primarily on the maximum size aggregate to be used. With the C060 gradation unit, it is possible to separate the aggregate into three or four size ranges. In this example, a four-bin separation will be used.
- It is necessary to consider the plant bin arrangement and the size of the screen for the fines bin to establish the best set-up for the most practical and efficient plant operation.
- In most cases, it is desirable to separate the aggregate into the bins in proportion to the bin storage capacities. To do this, it is necessary to know the gradation unit storage capacities. They are:

Bin #1	14.2 tons	46%
Bin #2	5.8 tons	19%
Bin #3	4.3 tons	14%
Bin #4	6.5 tons	21%
Gradation Unit (total capacity)	30.8 tons	100%

With the screens available, the smallest particle size that can be separated by the screening unit is the #8 material.

> NOTE: In many cases a separation at the #4 or #6 particle size instead of the #8 would be desirable, practicable, and satisfactory. The #6 material is used as the separation in this example to illustrate this point.

- Referring to the gradation chart (Figure 20), the vertical line for the #6 material size intersects the curve between two horizontal lines indicating that 47% of the aggregate is #6 and smaller.

> NOTE: Should specifications require the addition of mineral filler by the fines feeder the percent specified is subtracted from the percent determined for Bin #1 from the aggregate gradation chart.

Example: 5% mineral filler to be added by fines feeder.
47% of aggregate is #6 or smaller (Figure 20).
47% - 5% = 42% of aggregate is actually entering Bin #1.

Placing the first separation at the #6 material leaves a balance of 53% to be separated into three size ranges.

- Bin #2 has a capacity of 19%. Referring to the gradati6n curve (Figure 20) proceed from the #6 material line. Count up on the #6 material line 19% (each line represents 2%) and then read to the left to where the curve intersects the percentage line. The point of intersection lies between the 1/4-inch and the 3/8-inch vertical lines. By interpolating to the 5/16-inch

material, it is found that 18% will flow into Bin #2. (With available screens, it is possible to separate 5/16-inch material (refer to Figure 20). The 5/16-inch material is selected for the second separation leaving an aggregate balance of 35%.

- Bin #3 has a capacity of 14%. Count up 14% from the 5/16-inch separation and read to the left to where the percentage line intersects the gradation curve. The point of intersection lies between the 1/3-inch and 5/8-inch vertical lines. Since no screen is available to separate the 5/8-inch material the 1/2-inch material is selected as the separation allowing 10% of the aggregate to flow into Bin #3. The remaining 25% of the aggregate will flow into Bin #4.

Screen Selection.

- The vertical lines on which the bin separation were made on the gradation chart (Figure 20) represent the maximum size aggregate going into each bin. Screens must now be selected which will allow these maximum sizes to pass.
- When choosing screens, an important factor must be remembered. During operation, the vibration of the Screening deck reduces the clear space opening of the screens (Figure 21). The screen openings must be larger than the material size desired to pass through the screen. In Table 13, column B lists the screens available with the GQ60 gradation unit and column A lists the material size that will pass each screen.

Therefore: Bin #1 receives #6 material and smaller which requires a 5/32-inch screen to pass.
Bin #2 receives 5/16-inch to #6 material which requires a 3/8-inch screen to pass.
Bin #3 receives 1/2-inch to 5/16-inch material which requires a 9/16-inch screen to pass.
Bin #4 receives 1-inch material which requires a 1-1/8-inch screen to pass.

FIGURE 21. SCREEN OPENING

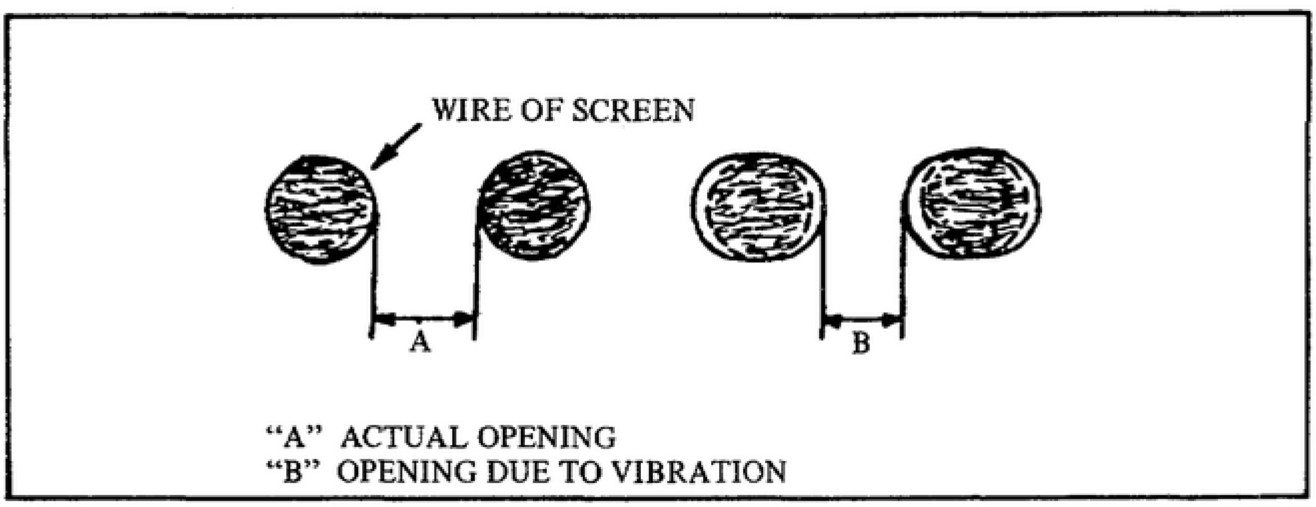


TABLE 13. SCREEN SIZES

A SIEVE SIZE OR MATERIAL SIZE	B SCREEN REQUIRED TO PASS MATERIAL
#8	1/10
#6	5/32
#4	1/4
5/16	8/8
1/2	9/16
3/4	7/8
1	1 1/8
1 1/4	1 3/8
1 1/2	1 5/8

Screens listed are the only screens available with the GQ60 gradation control unit.

Step 3. Determine the Dryer Capacity.

The dryer capacity is controlled by the amount of moisture that must be removed from the aggregate. Experienced engineers who become familiar with aggregates in an area can judge moisture content by field examination. The best method and most accurate method uses an oven with temperature control. The apparatuses used in the testing are usually found in the plant laboratory so the testing done is under controlled conditions. This determination of the moisture content can be best described in the following formula:

$$\text{Moisture content (w)} = \frac{\text{Weight of wet soil} - \text{weight of dry soil}}{\text{Weight of dry soil}} \times 100$$

When the aggregate moisture content has been determined, the dryer capacity is obtained from the Dryer Capacity Chart (Table 14 or Figure 22).

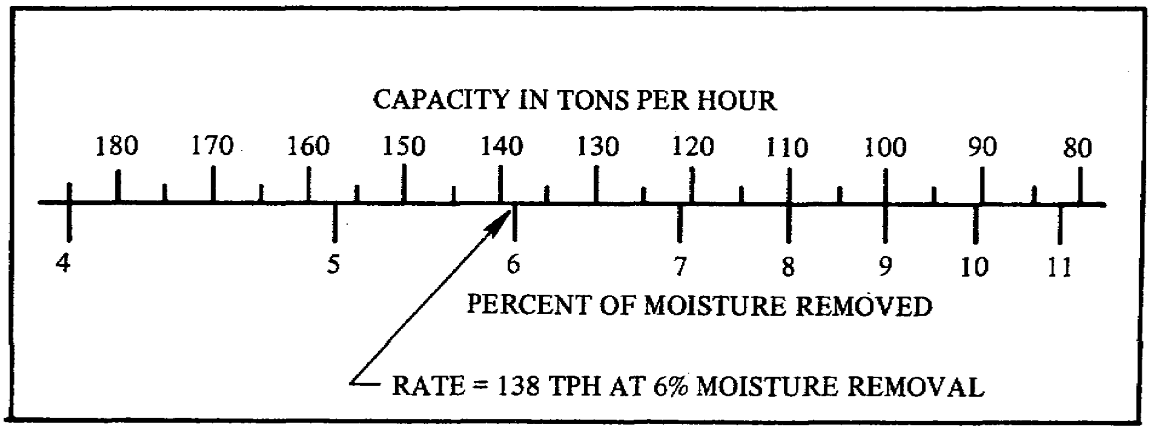
-Example: From Table 14 and Figure 22, dryer capacity equals 138 TPH at 6% moisture removal.

NOTE: Dried aggregates may contain no more than 0.5% moisture when mixed with asphalt cement in high type mixes.

TABLE 14. MODEL DA60 DRYER CAPACITIES

Moisture removed (%)	Capacity (TPH)	Fuel Consumption (gal/ton)
11	82	3.35
10	91	3.10
9	100	2.90
8	110	2.65
7	122	2.45
6	138	2.20
5	157	2.00
4	185	1.80

FIGURE 22. DA60 DRYER CAPACITY CHART



Step 4. Determine the Screen Capacity.

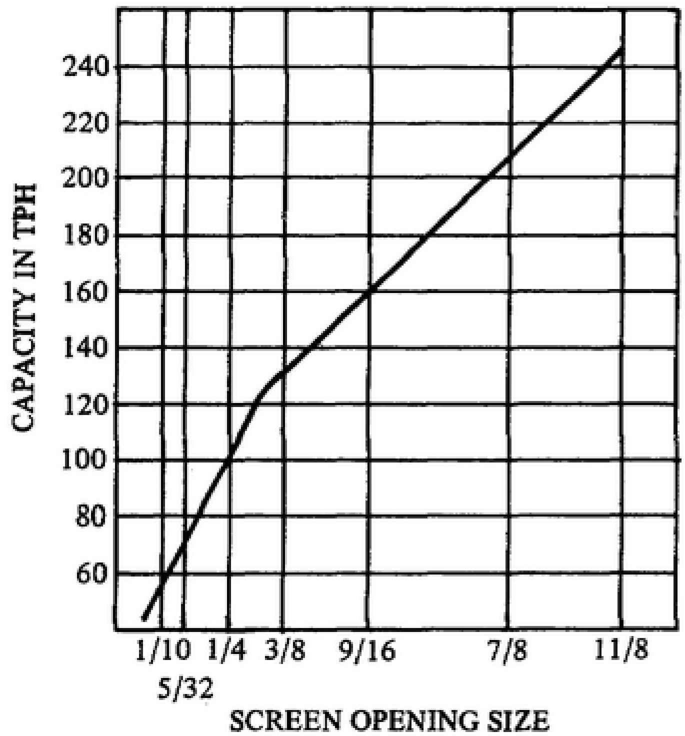
Screen capacity is determined by the amount of aggregate the smallest size screen will pass. Figure 23 illustrates the relationship between screen openings and aggregate processing rates for the screen which feeds Bin #1. Total screen capacity is then found by applying the following formula:

$$\text{Total screening capacity} = \frac{\text{Capacity of smallest screen}}{\text{\% Aggregate fed to Bin \#1}} \times 100$$

Example: Aggregate blend, Figure 20. Bins and fines feeder separations-given in Step 2 (Screen Selection) and in Figure 20. From Figure 20, the 5/324nch screen is the smallest to be used. Figure 23 reveals a passing rate of 70 TPH. The amount of aggregate fed to Bin #1 is 47%. Thus:

$$\text{Total screening capacity} = \frac{70}{47} \times 100 = 149 \text{ TPH}$$

FIGURE 23. SCREEN OPENING SIZE VERSUS CAPACITY



Step 5. Determine the Plant Output.

- In most cases, the dryer capacity will determine the plant output. Other considerations include ability of laydown crew to handle anticipated tonnage, number of haul units available, distance of haul, dryer capacity, and screening capability of the gradation unit.
- To determine the plant output, the percentage of dried aggregate that will be used in the total mix must be determined. If no mineral filler is added at the fines feeder, the percentage of bitumen subtracted from 100% will give the percent of dried aggregate.

Example: Percent bitumen 6.0%
Therefore: Percent aggregate = 100 - 6 = 94% dried aggregate
total mix

- If mineral filer is added after drying, subtract the percent bitumen from 100% to get the percent of total aggregate. Subtract the percent of mineral filler (expressed as a percent of total aggregate) from 100%. Multiply the two results to obtain the percent of dried aggregate in the total mix.

Example: Bitumen 6.0% (total mix)
Mineral filler 5.0% (aggregate in total mix)
100 - 6 = 94% (aggregate in total mix)
100 - 5 = 95% (dried aggregate in total aggregate)
0.94 x 0.95 = 0.893 (or) 89.3% dried aggregate (total mix).

$$\textbf{Example: Plant capacity} = \frac{\text{138 TPH (dryer capacity)}}{\text{0.893 (percent aggregate total mix)}} = \begin{matrix}\text{154.5 TPH}\\\text{(total mix)}\end{matrix}$$

Or if Mineral Filer is Added:

$$\textbf{Example: Plant capacity} = \frac{\text{138 TPH (dryer capacity)}}{\text{0.893 (\% dried aggregate total mix)}} = \begin{matrix}\text{154.5 TPH}\\\text{(total mix)}\end{matrix}$$

NOTE: It should be remembered that the preceding example is calculated for maximum capacity at 100% efficiency. During a sustained operation, due operating efficiency, the actual plant output will be somewhat lower than this example.

- In some instances it will be found that the screening capacity will be somewhat lower than the dryer capacity. This condition normally occurs with a low aggregate moisture content or when an extremely high percentage of fine aggregate is required for the mix. When this condition occurs, substitute the screening capacity for the dryer capacity in the preceding example.

Step 6. Determine the Feeding Rate.

- The percent required from each gradation unit bin and the percent of mineral filler to be fed by the fines feeder are expressed as a percent of the total aggregate. To determine the percent of the total required from each component, multiply the percent of total aggregate from each component by the percent of aggregate in the total mix.
- Refer to above. The percentages listed in the second column of this example are the percentages that were determined by screen selection. (Refer to Figure 20). However, these percentages are of the total aggregate in the mix. The aggregate makes up only 94% of the total mix. Therefore, by multiplying these percentages by 0.94, the percent of the total mix required from each feeding component is determined. As a check for accuracy, add the percent of total mix required from the four gradation unit bins and the percent of total mix required from the fines feeder. The sum of these figures must equal the percent of aggregate in total mix (in this case, 94%).
- The percent of total mix required from each component is then multiplied by the plant output. In Step 4, the plant output was calculated. In this example, 154.5 TPH will be the plant output. Refer to above. The figures listed in the right column are the required amounts of material from the appropriate component. Notice that these figures are in either lbs/rev or in TPH. Again, as a check for accuracy, add these figures. The sum must equal the plant output.

Step 7: Determine the Gradation Unit Feeder Speeds.

When the amount of material required from each bin has been determined, the apron feeder sprocket combination can be selected and installed. Table 15 shows the approximate feeding rates of the apron feeders for the six sprocket combinations available. Any sprocket combination can be used if the required feeding rate falls within the sprocket combination capacity range. However, best results will be obtained when the sprocket combination which allows the required feeding rate to fall near the center of the capacity range is selected.

> NOTE: A 29-tooth sprocket and a 43-tooth sprocket will be installed at the time of shipment. These should cover the normal capacity ranges desired.

- The feeding rates (from Determine the Feeding Rate paragraph), fall well within the capacity range of sprocket combination # l (Table 15). Therefore, combination #1 is selected for this example.

Example:	Bin #1	61.0	29T sprocket on Feeder #1
	Bin #2	26.1	
	Bin #3	14.5	43T sprocket on Feeder #2
	Bin #4	36.3	

TABLE 15. G6080 GRADATION UNIT APRON FEEDER CAPACITY CHART

APRON FEEDER SPROCKET COMBINATIONS	FEEDER NO. 1				FEEDER NO. 2			
	GATE 1		GATE 2		GATE 3		GATE 4	
	Min	Max	Min	Max	Min	Max	Min	Max
1) 29T on Fdr. No. 1 43T on Fdr. No. 2	9.5	126.2	9.4	93.9	8.9	16.5	16.5	62.6
2) 43T on Fdr. No. 1 29T on Fdr. No. 2	6.4	85.1	6.3	63.3	13.3	88.6	24.5	92.8
SPROCKETS LISTED ABOVE ARE NORMAL SETTINGS SPROCKETS LISTED BELOW ARE OPTIONAL								
3) 29T Spkts both shafts	9.5	126.2	9.4	93.9	13.3	88.6	24.5	92.8
4) 43T Spkts both shafts	6.4	85.1	6.3	63.3	8.9	59.7	16.5	68.6
5) 29T on Fdr. No. 1 58T on Fdr. No. 2	9.5	126.2	9.4	93.9	6.6	44.3	12.3	46.4
6) 43 T on Fdr. No. 1 58T on Fdr. No. 2	6.4	85.1	6.8	63.3	6.6	44.3	12.8	46.4

Note. Only these 6 combinations can be used together because of feeder head shaft spacing. The 58T cannot be placed on the No. 1 Feeder.

These capacity figures should be considered as a guide only. Figure based on 95% Eff #1, 85% Eff #2, 80% Eff #3, 70% Eff #4, 100 lbs. material.

These capacity figures are either pounds per revolution or tons per hour.

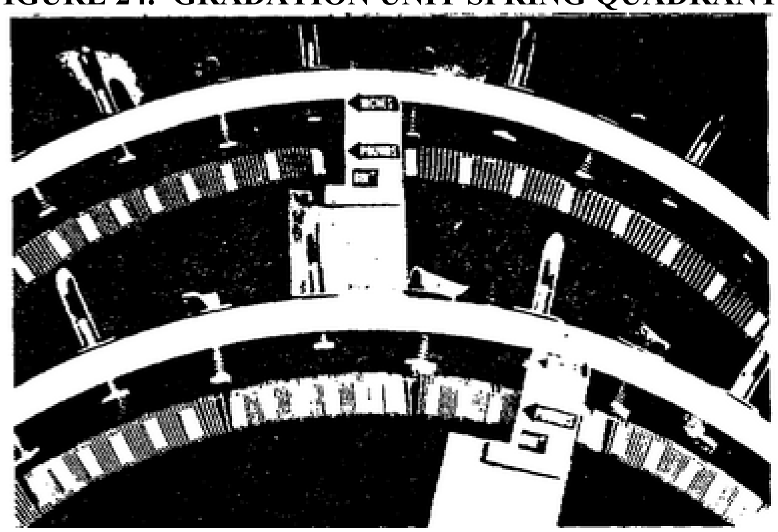
Step 8. Calibrate the Gradation Unit Feeder Gates.

Refer to Table 16 and Figure 24.

TABLE 16. CALIBRATION WORKSHEET

	[illegible]	MINUS	[illegible]	EQUALS	[illegible]	DIVIDED BY	[illegible]	EQUALS	[illegible]
TEST#1 8" GATE OPENING	Bin#1 235.8	-	(1) 34.6	-	(1) 201.2		Final 5714.26		(1) 100.6
	Bin#2 162.4	-	(2) 34.6	-	(2) 127.8		Less Initial 5712.26		(2) 63.9
	Bin#3 117.9	-	(3) 34.9	-	(3) 83.0		2.0	-	(3) 41.5
	Bin#4 133.0	-	(4) 34.8	-	(4) 98.2				(4) 49.1
TEST#2 8" GATE OPENING	Bin#1 182.06		(1) 34.6	-	(1) 147.46		Final 5717.94		(1) 101.0
	Bin#2 128.19		(2) 34.6	-	(2) 93.59		Less Initial 5716.48		(2) 64.1
	Bin#3 95.2	-	(3) 34.9	-	(3) 60.3	÷	1.46	-	(3) 41.3
	Bin#4 106.34	-	(4) 34.8	-	(4) 71.54				(4) 49.0
TEST#3 8" GATE OPENING	Bin#1 196.43		(1) 34.6	-	(1) 161.83		Final 5721.00		(1) 100.5
	Bin#2 140.2	-	(2) 34.6	-	(2) 105.6		Less Initial 5719.35		(2) 64.0
	Bin#3 103.21	-	(3) 34.9	-	(3) 68.31	÷	1.65	=	(3) 41.4
	Bin#4 115.98	-	(4) 34.8	-	(4) 81.18				(4) 49.2

FIGURE 24. GRADATION UNIT SPRING QUADRANTS



Due to the many variables encountered, such as weight per cubic foot, shape of particles, and aggregate gradation, it would be extremely difficult to make charts that would give the flow for all types of aggregate at a given gate opening. It is more satisfactory and accurate to calibrate the feeder gates for the material used on each job. The steps taken in feeder gate calibration are:

(1) Fills the gradation unit bins with hot, dried aggregate. Insure that the level of aggregate remains above the telltales while making the test.

(2) Weigh the test buckets and mark the height on each bucket. Number the buckets and position them under the test chutes.

(3) Set all four apron feeder gates at the 8" opening and run the feeders for two or three revolutions with the test gate levers in the "RUN" position.

(4) Stop the feeders and turn the test gate lever to the "TEST" position.

(5) Take the revolution counter reading and record it on the calibration work sheet (Table 16).

(6) Run the apron feeders until the test buckets are filled to approximately 3" from the top. Run continuously until the desired amount of material is in the test buckets.

> CAUTION: Do not over-fill the test buckets or the material will have to be discarded and the test run again.

(7) Stop the apron feeders and again record the revolution counter reading. The number of revolutions run is determined by subtracting the first counter reading from the last counter reading (Table 16).

(8) Weigh each test bucket carefully and subtract the weight of the bucket. The weight of each size material is divided by the number of revolutions run, giving the lbs. per rev. flow for an 8" gate opening for each size of aggregate (Table 9).

(9) Repeat and take the average of three tests at 3 different gate openings for accuracy. This is time consuming but may facilitate adjustments during plant operations.

(10) Lift all spring clamps away from the indicator spring (Figure 24). Each coil of the spring represents one pound per revolution. Stretch each spring from the 8" end until the gate pointer is over the coil corresponding to the pounds per revolution obtained in the tests. Each spring must be stretched uniformly over the entire 8" scale. Lock the springs by releasing the spring clamps at the 8" mark.

(11) Check the setting by running one or two weight samples at other gate openings below the 8" mark.

> NOTE: If the actual feeder delivery does not quite match the reading on the indicator spring, make the final adjustment of the spring at the nearest spring lock before moving the gate.

(12) As determined in Step 6, Determine the Feeding Rate, the amount of material required from each bin is:

Bin #1	39.5 lbs/rev
Bin #2	16.9 lbs/rev
Bin #3	9.4 lbs/rev
Bin #4	23.5 lbs/rev

After the gradation unit has been calibrated, the feeder gates are adjusted until the gate pointer corresponds to the lbs per rev (on the spring scale, Figure 24) to be used for that bin.

NOTE: The feeder gate setting should always be approached from the lower side.

This removes the backlash from the gate control linkage for greater accuracy.

(13) When all gates have been set to the proper openings, it is important to check the amount of aggregate actually being fed from each gate. The check is made by following the same procedure used to calibrate each gate. If a gate is improperly feeding, the gate opening is adjusted accordingly. If a gate is reset, another check should be made to insure accuracy.

NOTE: Gates feeding coarse aggregate should NOT be set lower than 1 1/2 times the largest aggregate size. For example, if a gate is feeding 1" material, it must not be set lower than 1 1/2. The aggregate portion of the continuous plant must be calibrated when the apron feeder sprockets are changed to increase or decrease the revolutions per minute of the feeder. Set pounds of aggregate delivered per revolution of the Gradation Unit Spring Quadrants. Insure that the springs are uniformly stretched across the scale and lock them in place. Set the indicator at the desired pounds per revolution.

Step 9. Calibrate the Fines Feeder.

If specifications require the addition of mineral filler to the mix, then the fines feeder must be calibrated. The fines feeder is calibrated in much the same way as the gradation unit feeder gates. (Refer to Table 17). The results of the calibration tests are graphed on standard graph paper (Figure 25) having vertical lines representing the adjusting arm setting and horizontal lines representing the lbs. per rev. delivered. The graph is used to determine the adjusting arm setting to deliver the required amount of fines.

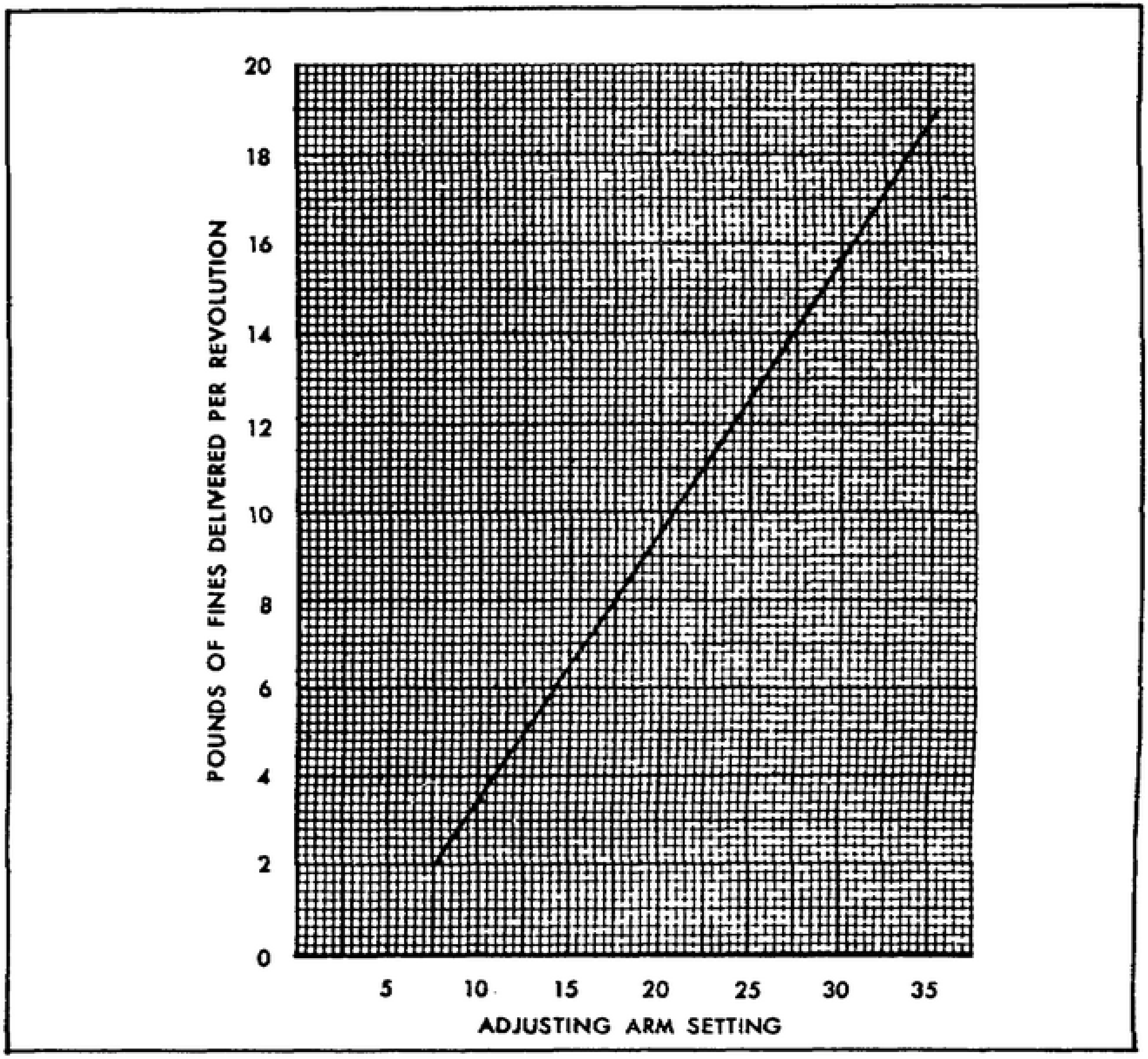
Example: Required fines feeding rate = 7.3 lbs/rev. The adjusting arm setting (from Figure 25) = 18.

Plot pounds of fines delivered per revolution at the different adjusting arm settings on Fines Feeder Gate Calibration Graph (Figure 25) and connect points with a straight line.

TABLE 17. FINES FEEDER CALIBRATION WORKSHEET

BE SURE THAT GRADATION UNIT FEEDERS ARE DISENGAGED AND THAT FINES FEEDER HOPPER IS FILLED WITH AT LEAST 300 POUNDS OF FINES. HINGED DOOR IS OPENED SO THAT IT LIES BACK AGAINST HOUSING. SHORT SCREWS MUST BE FILLED WITH MATERIAL BEFORE CALIBARTION IS BEGUN.	ADJUSTING ARM SETTING (USE SETTING OF 10 FOR FIRST TRIAL THEN 30 AND 50)		
	10	30	50
Enter initial revolution counter reading and run feeder until test bucket is half full. Weigh the bucket and fines delivered during test and enter weight at right	97.06	109.00	96.82
Less weight of empty bucket	− 28.56	− 28.56	− 28.56
Equals weight of fines delivered	68.50	80.54	68.26
Revolution counter reading at end of trial	1557.58	1562.78	1565.67
Less initial revolution counter reading	−1537.45	−1557.60	−1562.81
Equals revolutions run	20.13	5.18	2.86
Weight of fines delivered	68.50	80.44	68.26
Divided by revolutions run	÷ 20.13	÷ 5.18	÷ 2.86
Equals pounds delivered per revolution	3.4	15.7	23.9

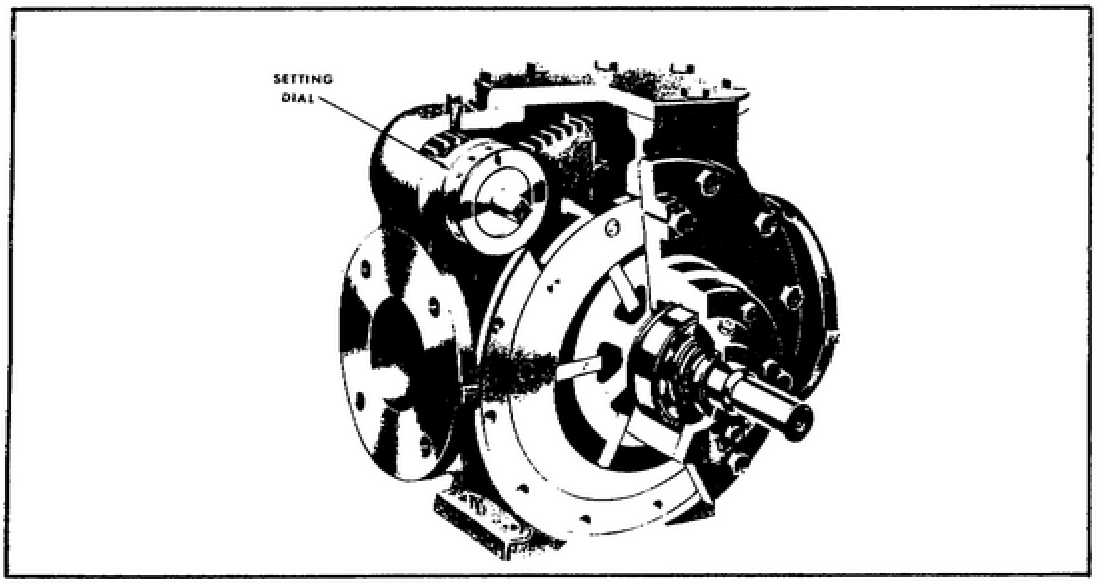
FIGURE 25. FINES FEEDER CALIBRATION GRAPH



Step 10: Calibrate the Asphalt Metering Pump.

The amount of asphalt in a given specification is written as a percent of the total mix (plant output). Since the final plant output is dependent on the amount of aggregates being processed by the dryer, the amount of asphalt is regulated in direct proportion at the same time that the amount of aggregates to be fed by the apron feeders is determined (Step 6). The asphalt flow is controlled by the positive displacement, variable volume metering pump (Figure 26).

FIGURE 26. METERING PUMP



To calibrate the asphalt metering pump, it is necessary to establish the type of bituminous material, specific gravity of bitumen material, and bitumen temperature near the metering pump. The pump is calibrated to determine the setting which will deliver the required asphalt to the mix. The pump may be calibrated by either the arithmetic method or the pump output method.

(1) Arithmetic method (Specific gravity and temperature known). Refer to Step 9. This example will use 85-100 penetration asphalt cement having a specific gravity of 1.015. The mixing temperature will be 300°F.

a. Determine the lbs per rev of titumen to be used in the mix (9.3 from Step 6).

b. Calculate the lbs per gal at mixing temperature of the bitumen being used (refer to Step 10). As established above, the mixing temperature of 85-100 penetration asphalt cement is 300°F. Refer to Table 18. In this table, "t" equals the mixing temperature of the asphalt and "M" equals the multiplier to be used to convert the weight of one gallon of asphalt at 60° to the weight of one gallon at mixing temperature. In Table 18 find 300° in the column headed "t." To the right of the column headed "M," it is seen that the multiplier is 0.9187.

TABLE 18. TEMPERATURE-VOLUME CONVERSION DATA FOR BITUMINOUS MATERIALS

t	M	t	M	t	M	t	M
60	1.0000	135	0.9740	210	0.9486	285	0.9236
65	0.9983	140	0.9723	215	0.9469	290	0.9220
70	0.9965	145	0.9706	220	0.9452	295	0.9204
75	0.9948	150	0.9689	225	0.9436	300	0.9187
80	0.9930	155	0.9672	230	0.9419	305	0.9171
85	0.9913	160	0.9655	235	0.9402	310	0.9154
90	0.9896	165	0.9638	240	0.9385	315	0.9138
95	0.9878	170	0.9621	245	0.9369	320	0.9122
100	0.9861	175	0.9604	250	0.9352	325	0.9105
105	0.9844	180	0.9587	255	0.9336	330	0.9089
110	0.9826	185	0.9570	260	0.9319	335	0.9073
115	0.9809	190	0.9553	265	0.9302	340	0.9057
120	0.9792	195	0.9536	270	0.9286	345	0.9040
125	0.9775	200	0.9520	275	0.9269	350	0.9024
130	0.9738	205	0.9503	280	0.9253	355	0.9008

Group 0 — Specific Gravity at 60° above 0.966.
t = Observe temperature, degrees F.
M = Multiplier for correcting bitumen volumes to the basis of 60°F.

Refer to Step 10. Once the temperature factor is obtained from Table 18, it is multiplied by the specific gravity of the asphalt cement. The result of this multiplication is a conversion factor. The conversion factor (in this example, 0.9325) is then multiplied by the average weight of one gallon of asphalt cement at 60°F.

> NOTE: The manufacturer has established 8.328 lbs per US gal. and 10.002 lbs per Imperial gal. as the average weight of asphalt cement at 60°F. For the purposes of this calculation, these figures are considered constant.

By multiplying the conversion factor 0.9325 by 8.328 lbs per US gallon, it is determined that the asphalt being used will weigh 7.77 lbs per gal at mixing temperature.

c. Determine the pump setting (Table 19).

The METERING PUMP CAPACITY CHART (Table 19) lists the discharge rate of the metering pump in lbs per rev for the given pump setting. The chart is based on asphalt weighing 7.85 lbs per gallon at mixing temperature.

If in the above example, the calculated lbs per gallon had been 7.85, then the pump setting required to deliver 9.3 lbs per rev may be obtained directly from the chart.

TABLE 19. METERING PUMP CAPACITY CHART

PUMP SETTING	10	20	30	40	50	60	70	80	90	100
Lbs Per Rev.	1.67	3.34	5.0	6.67	8.34	9.22	11.8	13.2	15.3	16.7

Example: Assume that the calculated lbs per gallon in the above example is 7.85.

The required pump discharge rate is 9.3 lbs per rev (from Step 6). This feeding rate falls between 9.22 lbs per rev and 11.8 lbs per rev on the chart. By interpolating, it is found that the required pump setting is 60.3.

NOTE: Since the pump dial is calibrated from 0 to 100 in increments of 1, the .3 must be estimated between 60 and 61. When the pump has been set and locked, a check should be made to insure that the proper pump output is being obtained.

If the calculated lbs per gallon is other than 7.85, the required feeding rate must be adjusted before the pump setting is determined.

Refer to Step 9-1. In this example, the calculated lbs per gallon is 7.77. In this case, the 9.3 lbs per rev delivery rate must be adjusted before it is used with the METERING PUMP CAPACITY CHART to determine the pump setting. To do this, the average weight of asphalt at mixing temperature (7.85 lbs per gal) is divided by the calculated weight of one gallon of the asphalt being used (7.77 lbs.). The result is then multiplied by the required delivery rate (9.3 lbs per rev). The corrected delivery rate based on 7.85 lbs per gallon is found to be 9.395 lbs per rev rounded to 9.4 lbs per rev. Referring to the METERING PUMP CAPACITY CHART (Table 19), it is found that to deliver 9.4 lbs per rev, a setting of 60.7 is required.

NOTE: The adjusted lbs per rev serves as a correction factor for the METERING PUMP CAPACITY CHART. It must be remembered that, due to the difference in the weight of the asphalt being used and the basis of the chart, though 9.4 lbs per rev is used to set the pump, the actual pump output will be 9.3 lbs per rev.

(2) Pump output method (specific gravity NOT known). This method of calibrating the metering pump consists of a series of weight samples and

pump adjustments. It is very important that the asphalt being used is at the prescribed mixing temperature before the tests begin. The procedure for calibrating by the pump output method is as follows:

a. Determine the approximate pump setting (Figure 25) from the METERING PUMP CAPACITY CHART (Table 19). As determined in Step 5-1, the required feeding rate is 9.3 lbs per rev. By interpolating on the chart, it is found that the setting required to deliver this rate is 60.3.
b. Set the pump to 60.3 and take a weight sample (Figure 26). The procedure for taking a weight sample is as follows:
    - Obtain two test buckets of approximately 25 gallons each.
    - Weigh one test bucket and record the weight.
    - Place the other test bucket under the sample pipe.
    - With the control valve in the test position, run the pump until the sample pipe begins to discharge asphalt. Stop the pump and allow the pipe to drip for one (1) minute. Remove the test bucket and discard the asphalt.
    - Place the weighed bucket under the sample pipe and record the revolution counter reading.
    - Run the pump until the test bucket is between 1/2 and 3/4 full. Stop the pump and allow the sample pipe to drip for one (1) minute.
    - Weigh the sample and subtract the weight of the bucket to obtain the weight of the asphalt.
    - Record the revolution counter reading and subtract the reading at the beginning of the test to obtain the number of revolutions run.
    - Divide the weight of the asphalt by the number of revolutions to determine the lbs per rev being delivered.

NOTE: Always allow the sample pipe to drip for one (1) minute before weighing the test bucket. Be sure to weigh the test bucket before each test, as asphalt clinging to the sides of the bucket will change its weight.

c. Adjust the metering pump setting as necessary and take another weight sample following the procedures outlined above to check for accuracy.
d. Continue this procedure until the output of the pump is equal to the required lbs per rev for the mix.

NOTE: When the weight sample equals the required lbs per rev, make at least one final weight sample to insure accuracy.

Step 11. Determine the Initial Cold Feed Settings.

(1) The percentage of each aggregate stockpile used in the aggregate blending operation (Table 12) serves as a guide in determining the initial cold

feed gate openings. The gates are set to estimated openings which will feed the approximate amount of aggregate required. Due to varying aggregate weights and sizes, accurate gate settings can be made only after the operation begins. Final gate adjustments must be made to prevent the gradation unit bins from overflowing or running low. Several adjustments may be necessary to maintain a balanced aggregate flow to the gradation unit.

(2) One method of estimating the initial cold feed settings is shown in the following example. In this example, the total aggregate in tons per hour must be determined. This is done by dividing the dryer capacity (138 TPH) by the percent of dried aggregate in the total aggregate (0.95). In this example, 145.3 tons of aggregate will be required per hour.

(3) The total aggregate is then multiplied by the percent required from each aggregate stockpile (coarse agg, 0.45, fine agg, 0.30, sand, 0.20) to determine the feeding requirements from each stockpile. Here it is seen that the mix will require 65.4 tons of coarse aggregate, 43.6 tons of fine aggregate, and 29.1 tons of sand each hour. The cold feed gates must now be adjusted to feed approximately these amounts.

(4) Since the coarse aggregate must be fed at a rate of 65.4 TPH, it is recommended to divide this aggregate equally between cold bins #3 and #4. By doing this, bins #3 and #4 will be feeding coarse aggregate at a rate of 32.7 TPH each.

(5) To determine the gate openings required to feed this amount of coarse aggregate, refer to Table 20. This table shows the approximate feeding rate of the reciprocating feeder for various types of material.

TABLE 20. FEEDING RATE (TON PER HOUR) - MODEL 815 FEEDER 12-INCH GATE WITH RECIPROCATING FEEDER

Gate opening	No. 4 sand	1 1/4" gravel	3/8" Crusher screening	1/2" Crushed stone	1 1/4" Crushed stone	1 1/4" Stone and sand blend
	Ton	Ton	Ton	Ton	Ton	Ton
Inch	8.2	7.3	6.3	7.0	5.6	6.6
2 1/2	10.1	9.9	8.2	9.0	7.5	9.0
3	12.2	12.5	10.5	11.0	9.9	11.3
3 1/2	14.2	15.0	12.0	13.0	11.3	13.7
4	16.3	17.5	13.9	15.1	13.1	16.1
4 1/2	18.3	20.0	15.8	17.7	15.0	18.5
5	19.7	22.6	17.1	20.4	17.4	20.9
5 1/2	22.4	25.1	20.0	21.7	18.8	23.3
6	24.4	27.7	22.5	23.0	20.7	25.7
6 1/2	26.8	30.3	23.4	25.1	22.3	28.1
7	28.5	32.8	25.3	27.1	24.5	30.5
7 1/2	30.5	35.4	27.2	29.5	26.9	32.9
8	32.6	37.9	29.2	31.1	28.3	35.3
9	36.7	43.0	33.0	34.9	32.1	40.0
10	40.7	48.2	36.8	39.2	35.9	44.8

(6) The sieve analysis of the coarse aggregate (Table 12, gradation of material) shows that this material contains 1" maximum size aggregate with considerable fine material. Therefore, the coarse aggregate may be classed as sand/aggregate mixture. The proper column to use in this case would be the 1 1/4" Stone and Sand Blend (Table 20).

(7) As previously determined, bins #3 and #4 must feed 32.6 TPH each. Reading down the proper column on Table 13, it is seen that the capacity closest to this is 32.9 TPH requiring 7 1/2 inch gate opening. Since the initial gate settings are only approximations, gates #3 and #4 are each set at 7 1/2" openings and will be adjusted as necessary when operations begin.

(8) Bins #1 and #2 feed the fine aggregates onto tie rubber belt conveyor of the cold feed unit. The proper table to use to determine the gate openings for these bins is Table 21.

TABLE 21. FEEDING RATE (TONS PER HOUR) - MODEL 815 FEEDER 12-INCH GATE WITH BELT CONVEYOR

Gate Opening Inch	Sand Graded From 1/4" thru 200# Mesh Tons	Fine Stone or 1/2" to 10# Mesh Tons
1.0	11.4	9.4
1.5	18.0	16.0
2.0	24.8	22.5
2.5	31.4	29.0
3.0	38.0	35.6
3.5	44.8	42.1
4.0	51.6	48.6
4.5	58.2	55.0
5.0	64.9	61.6

(9) The fine aggregate in bin #1 consists of 3/4" minus material. However, as seen in the sieve analysis, only 2 percent of this material is larger than 1/2". The proper column in Table 21 to use to determine the gate opening would be the "Fine Stone" column. The required feeding rate from bin #1 is 43.6 TPH. Reading down the "Fine Stone" column, it is seen that 43.6 TPH is closest to the listed capacity of 42.1 TPH. Therefore, the #1 gate is set at a 3" opening and will be adjusted as necessary when operations begin.

(10) Bin #3 is to feed sand at a required rate of 29.1 TPH. The proper column to use to determine the gate opening is the "Sand" column. Reading down the "Sand" column, it is seen that the required rate of 29.1 TPH falls approximately half way between the listed capacities of 24.8 TPH. Therefore, gate #1 is set at an opening approximately half way between the openings listed for these capacities (2 1/4") and will be adjusted as necessary when operations begin.

As determined above, the cold feed gates are set as follows:

Gate #1	2 1/4"
Gate #2	3"
Gate #3	7 1/2"
Gate #4	7 1/2"

NOTE: When operations begin it may be necessary to make adjustments of the cold feed gate openings. Several adjustments may be necessary to maintain a balanced flow of aggregates to the gradation unit.

Step 12. Check All Settings.

(1) Once the mixing plant has been calibrated, all settings must be checked to insure accuracy. When it is verified that all settings are correct, the mixing operation may begin.

(2) At the start of the mixing operation, a Marshall Stability test and an extraction test should be taken by the plant laboratory using samples of the finished mix. The plant is operated only long enough to mix four truck loads. Four samples are then taken (one from each truck load to obtain a representative sample). The plant is then shut down until the results of the Marshall and extraction tests can be compared with the mix design for compliance with specifications. If necessary, proper adjustments are made to secure a conforming mix. If adjustments are made, four additional truck loads are mixed, sampled, and tested. When it is determined that the plant mix conforms to specifications, the plant may be placed in continuous operation.

NOTE: The plant must not be placed in continuous operation until the variations in test properties are within allowable tolerances.

PRACTICE EXERCISE FOR LESSON 6

Instructions

Check your understanding of Lesson 6 by completing the practice exercise. 'There is only one correct answer to each question. Try to answer all of the questions without referring to the lesson materials.

When you have completed all of the questions, turn the page and check your answers against the correct responses. Each correct response is referenced to specific portions of the lesson material so that you can review any questions you have missed or do not understand, before continuing to the next lesson.

1. How far can a mix normally be moved in a temperate climate?

   a. up to 50 miles
   b. up to 100 miles
   c. up to 150 miles
   d. up to 200 miles

2. What should the general location of a plant include?

   a. a good supply of water
   b. a good supply of asphalt
   c. a good grade of aggregate
   d. a good roadnet

3. Where should the specific location of a central plant be?

   a. in an area with light traffic
   b. in a well drained area with stable soil
   c. on top of a large hill with a good water supply
   d. in an area with heavy traffic

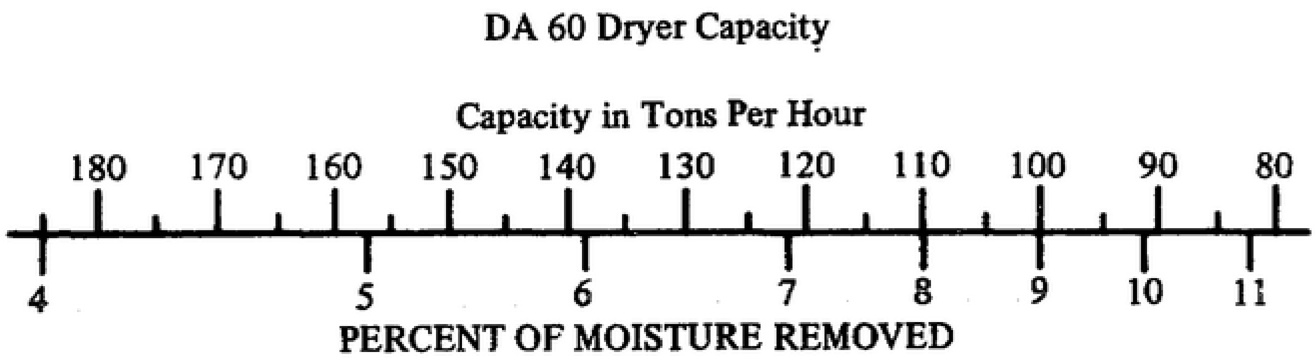
4. What are the three classifications for an asphalt mix plant?

   a. hot type, cold type, and intermediate type
   b. high type, intermediate type, and soil stabilization
   c. dry type, wet type, and mixed type
   d. intermediate type, heavy type, and light type

5. What components are typical support equipment for use with a 100 to 150 TPH asphalt plant?

   a. hot oil heater and asphalt meter
   b. truck-mounted fuel tank and a cold water sprayer
   c. solid asphalt tanks and asphalt gas heater
   d. hot water sprayer and a truck-mounted gasoline heater

6. Using the chart below, determine the aggregate dryer capacity in TPH when the moisture content of the aggregate is 8 percent.



   a. 100 TPH
   b. 105 TPH
   c. 110TPH
   d. 115TPH

7. Using the following data, identify the TPH pant capacity:
   Aggregate moisture content 10%
   Percent aggregate in total mix 92%
   Dryer capacity ....91 TPH
   Screen capacity...110 TPH
   a. 154.5
   b. 136.3
   c. 105.2
   d. 196.5

8. The feeding rate for each feeding component in an asphalt mix plant is determined by:

   a. dividing the plant capacity by the various screen sizes.
   b. multiplying the percent aggregate contained in each component by percent of asphalt in the mix.
   c. determining the asphalt pump output.
   d. multiplying the plant capacity by the percent of total for each component.

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ANSWER SHEET FOR PRACTICE EXERCISE

Lesson 6	Learning Event
1. a	1
2. d	1
3. b	1
4. b	2
5. a	3
6. c	4
7. c	4
8. d	4

Lesson 7
MAINTENANCE OF BITUMINOUS SURFACES

TASK: Plan Maintenance of Bituminous Surfaces

CONDITIONS: Given this subcourse, a No. 2 pencil, a calculator (recommended) and an ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 75 percent of the examination questions.

CREDIT HOURS: 1

REFERENCES

TM 5-337, Paving and Surfacing Operations

ST 5-330-8, Special Text, Flexible Pavements

Learning Event 1
REPAIRS FOR BASE AND SUBGRADE FAILURES

INTRODUCTION

Bituminous surfaces, like most other surfaces, require frequent maintenance. It is seldom possible to concentrate enough effort to prevent failures in bituminous surfaces; therefore, it is essential for engineer officers and construction foremen to understand the principles, equipment, and procedures required for adequate maintenance and repairs.

Bituminous surfaces are repaired or resurfaced with other bituminous materials, because of their plastic and adhesive characteristics. The original pavement actually is improved when the new material is properly placed. A bituminous surface is a flexible surface; therefore, it is directly dependent upon its foundation (base course, subbase, subgrade, etc.) for its load carrying capacity. Whenever a foundation failure occurs, that part of the wearing surface which lies above the weakened area will also fail.

TYPES OF FOUNDATION FAILURES

Moisture (Drainage)

The greatest single enemy of any pavement structure is moisture. Moisture saturation must be prevented, as much as possible. The only positive approach to keeping the foundation dry is to install complete drainage systems.

Frost Action

Frost action may be another cause of foundation failure. Water freezing in the bases, select materials, or subbase will cause the formation of ice lenses and frost voids, and a resulting heave in the bituminous surface.

Poor Soil and Construction

In the Theater of Operations time and equipment are not always available to properly select construction materials and adequately place and compact the foundation. For this reason the foundation is not adequate to withstand the pounding of military traffic.

Overloading

A flexible pavement structure may be able to carry its design load indefinitely with never a failure. However, if an extremely heavy load passes over the surface, it may fail. On both military and civilian roads and airfields, load limits are usually set so that failures from overloading will not occur.

Learning Event 2
REPAIRS FOR SURFACE FAILURES

The principal cause of surface failure is subgrade or base failure. Surface failures are also caused by disintegration, and instability of the surface course. Types of surface failures are described below.

TYPES OF SURFACE FAILURES

Disintegration

Disintegration means the decomposition of the surface. Under this heading, there are several possible causes that are listed below:

- Hardening of asphalt films
- Insufficient asphalt
- Stripping of binder

Instability

An unstable wearing surface is incapable of withstanding deformation under the impact of traffic. Some of the causes for instability and their effects are listed below:

- Excess asphalt (binder) will cause bleeding
- Smooth or rounded aggregate will cause low friction
- Too soft an asphalt
- Low density (lack of proper compaction)
- Uncured prime or tack coats will soften lower portion of pavement
- Too much prime or tack will cause instability
- Dirt between pavement and base will cause a slippage plane
- Lack of bond between layers will move under traffic

FAILURE EFFECTS

The following conditions may occur from either foundation or surface failures.:

- Potholes (chuckholes) caused by lack of binder (asphalt), poor drainage, or excess openings in the mix, and structural weakness.
- Longitudinal or transverse cracking caused by subgrade shrinkage, or by swelling and heaving in the soils.
- Ravelling in a pavement caused by insufficient asphalt (binder), burning of binder material or aggregate.
- Bleeding surface caused by excess asphalt content.
- Alligator cracks caused by lack of support.

REPAIR METHODS

Next, and the most important, are repair methods required to correct deficiencies in the surface. Patching requires skill and close supervision. The

prompt repair of small breaks will have much to do with keeping down maintenance efforts. Types of patching are shown below:

- Skin patch
- Penetration patch
- Pre-mix patch
- Seal coat

PRACTICE EXERCISE FOR LESSON 7

Instructions

Check your understanding of Lesson 7 by completing the practice exercise. There is only one correct answer to each question. Try to answer all of the questions without referring to the lesson materials.

When you have completed all of the questions, turn the page and check your answers against the correct responses. Each correct response is referenced to specific portions of the lesson material so that you can review any questions you have missed or do not understand, before continuing to the next lesson.

When you have completed all seven lessons and your review, you can continue to the examination.

1. What would frost action cause in a bituminous surface?

   a. heaves in the surface
   b. failure of the asphalt
   c. rounding of the aggregate
   d. smoothing of the aggregate

2. What is the best way to keep pavement foundations dry?

   a. Construct foundation on a down slope.
   b. Install complete drainage system.
   c. Increase thickness of the subgrade.
   d. Decrease the thickness of the base course.

3. What is the cause of surface ravelling in a pavement?

   a. excess water on the surface
   b. lack of rounded aggregate
   c. insufficient asphalt
   d. excess asphalt binder

4. What would cause bleeding in a surface pavement?

   a. moisture
   b. excess asphalt
   c. insufficient asphalt
   d. lack of bond between layers

ANSWER SHEET TO PRACTICE EXERCISE

Lesson 7	Learning Event
1. a	1
2. b	1
3. c	2
4. b	2